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Massachusetts. Senate.

REPORT

with Reports of

OF THE

E. F. Jenks

COMMISSIONERS

UPON THE

Troy and Greenfield Railroad,

AND

HOOSAC TUNNEL.

FEBRUARY 28, 1863.

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BOSTON:
WRIGHT & POTTER, STATE PRINTERS,
No. 4 SPRING LANE.
1863.

SENATE....No. 93.

Commonwealth of Massachusetts.

In Senate, February 25, 1863.

Ordered, That His Excellency the Governor be requested to communicate to the legislature, without delay, any and all the information pertaining to the Troy and Greenfield Railroad and Hoosac Tunnel, that may have been procured by the commissioners appointed under chapter 156 of the Acts of 1862, in order that time may be afforded for such inquiry and examination as will enable the legislature to act intelligently on any question in regard to the enterprise that may properly come before it.

Sent down for concurrence.

S. N. Gifford, *Clerk*.

House of Representatives, February 26, 1863.

Concurred.

W. S. Robinson, *Clerk*.

*

Commonwealth of Massachusetts.

Executive Department, Boston,
March 12th, 1863.

To the Honorable the Senate :

I have the honor to communicate for the use of the legislature, the Report of Messrs. John W. Brooks, Samuel M. Felton, and Alexander Holmes, Commissioners appointed under chapter one hundred and fifty-six of the Acts of 1862, providing "for the more speedy completion of the Troy and Greenfield Railroad and Hoosac Tunnel."

By this report, made to the governor and council, it is apparent that the Commissioners have discharged the duties of investigation and inquiry into the whole subject of finishing the Troy and Greenfield Railroad, and of tunnelling the Hoosac Mountain—including the most economical, practical, and advantageous methods for the completion of the work, the cost of fitting the railroad and tunnel for use, the time within which the tunnelling of the mountain can be completely effected, the probable cost of the enterprise, the probable pecuniary value of the road and tunnel, with the sources and probable amount of traffic and income—in a manner at once elaborate, comprehensive, instructive and convincing. Their report is attended by several plates, carefully illustrating those features of the proposed work more easily presented or explained by the aid of maps or plans, and is accompanied also by a report of Mr. Charles S. Storrow on *European Tunnels*, who at the request of the Commissioners, with the approval of the governor and

council, visited Europe for the purpose of examining the most important tunnels already constructed, and especially that now in progress under the Alps at Mont Cenis, between France and Italy, which in many respects is supposed to be a work more nearly analogous to that projected under the Hoosac Mountain, than any other in the world. It is accompanied also by the respective reports made to the Commissioners by Messrs. Benjamin H. Latrobe and James Laurie, on the Hoosac Tunnel and Troy and Greenfield Railroad. The first contains observations and opinions which were the result of Mr. Latrobe's personal examination of the Hoosac Mountain and Tunnel, seen in the light of a considerable professional experience in works of a similar character, though of proportions less gigantic; the second (namely, the report of Mr. Laurie,) exhibits a minute and scientific survey of the whole route of railroad and tunnel, with elaborate calculations. This mass of documentary matter, with the profiles, maps and plans contained therein, or prepared for ampler illustration and referred to in these reports, presents, as I believe, an exhaustive treatise upon the subject intrusted to the investigation of the Commissioners, in all its particulars and relations. It is, itself, a monument of industry and learning, and of practical as well as of professional judgment.

The report of the Commissioners establishes *the feasibility of the grand enterprise of tunnelling the Hoosac Mountain*, and the necessity of ultimate and essential changes in the details of the railroad line, of essential and important changes in the character and quality of the work upon the road and bridges, and of the enlargement of the tunnel itself; and also the necessity on the part of the State, of taking into its own hands the enterprise of constructing the tunnel, undertaking the work on its own account, controlling its own agents and holding them directly responsible for the integrity of their management. This course is, in the judgment of the Commissioners, in a work so exceptional and peculiar, an essential condition of energy, economy and success.

The Commissioners find that the period of eight years will be necessarily employed in the accomplishment of this work. The advances already made by the Commonwealth to the Troy and Greenfield Railroad Company, with interest to January 1,

not acc. c.1

1863, including a special appropriation of $175,000 made last year, amount to $968,862. The additional interest at five per cent. for eight years, amounts to $462,585. The cost, therefore, in which the State is already involved towards this enterprise, assuming its completion in eight years, is $1,431,447. The cost of completing the tunnel is estimated by the Commissioners at an additional sum of $2,696,229, to which should be added interest during construction, $522,094, giving a result of $3,218,323. The estimated expenditure immediately required to complete the road east of the tunnel, is $447,060, the interest on which item it is assumed will be paid out of earnings to be received during the construction of the tunnel. The cost of permanent work from time to time, to replace the present temporary structures as they fail, is estimated at $50,000. The cost of straightening and improving the line east of the tunnel, to be done as the last thing before the tunnel is completed, is placed at $155,000. These three last enumerated items involve an expenditure of $652,060, deemed necessary to establish the road from Greenfield to the mountain on such a footing as to enable it to meet reasonable expectations as a through route. The cost of constructing the two miles, from the western terminus of the tunnel to North Adams, is stated at $67,500. The expense of the additional dépôt buildings, shops, &c., for the completed line, will be $75,000, and the cost of the rolling stock $275,000.

The total estimated cost of road and tunnel, including advances hitherto made by the Commonwealth, with interest on past and future advances and expenditures, at five per cent., compounded until the expected completion of the tunnel, and including also the expense of altering and enlarging the work already bored, straightening and improving the road and bridges, amounts therefore, in the whole, to the sum of $5,719,330.

It will be remembered that the Act under which the Commissioners were appointed, and under which the prosecution of the work of constructing the road and tunnel was authorized, with the approval of the governor and council, to be continued, contemplated expenditures and advances, which, together with all sums hitherto advanced thereon by the Commonwealth,

should not exceed $2,000,000 in the aggregate. But the total amount of advances made by the Commonwealth prior to the date of suspension of work in the summer of 1861, was $778,695, which with the additional payment of $175,000 appropriated under the Act of 1862, will give a total advancement, excluding interest, of $953,695 already absorbed out of the appropriation of only $2,000,000, of which the statutes thus far contemplated the expenditure. The cost of completing the whole work is, therefore, so considerably beyond the unused portion of the $2,000,000 appropriated, as imperatively to demand still further legislation to render the prosecution of the enterprise practicable by the commissioners.

It will be observed that the Commissioners' Report, with the attendant documents, is communicated in print, the Commissioners having been directed, for the purpose of avoiding the delay consequent upon printing the documents after presentation, to make their report originally in print. It is understood that copies are ready for immediate distribution to the members of the general court.

Among the successful efforts of the commission, the legislature will be gratified to notice that of securing an agreement in writing from the Fitchburg Railroad, the Vermont and Massachusetts Railroad and the Troy and Boston Railroad Companies, for the contribution by each of those companies, to the Commonwealth, in consideration that it shall construct and complete the Troy and Greenfield Railroad and Hoosac Tunnel, of twenty per cent., or one-fifth of their gross earnings, respectively, upon the passenger and freight business coming upon their roads from any part of the Troy and Greenfield Railroad. This agreement, however, provides for its own modification or annulment when the earnings of the Troy and Greenfield Railroad shall have reached a point indicative of established and permanent success; the particular tests of that success being pre-determined in the agreement. And in this connection I have also to invite the attention of the general court to a letter from Mr. Brooks, the chairman of the commission, addressed to myself, bearing date of this day, communicating a correspondence between himself and the presidents of the Fitchburg Railroad Company and the Vermont and

Massachusetts Railroad Company, concerning a proposed lease of that part of the Troy and Greenfield Railroad lying east of the tunnel, for a period of six years and pending the construction of the tunnel. This negotiation was initiated to enable the State to determine whether it would be wise to complete at once the railroad between the eastern terminus of the tunnel and the town of Greenfield, of which the proposal of the Fitchburg and the Vermont and Massachusetts Railroad Companies, dated yesterday, is a material encouragement.

I deem it my duty, also, to furnish for the information of the legislature, a letter received this day from the chairman of the Commissioners, accompanied by a careful statement prepared by himself, exhibiting the whole amount heretofore expended upon the construction of that part of the Troy and Greenfield Railroad between Greenfield and the tunnel. This statement exhibits the quantity and kind of work done upon that piece of road before the suspension of its progress in the summer of 1861. The result shows that the Commonwealth had advanced at that time, out of the $650,000, the sum of $481,428, of which amount the company were only entitled to have received $350,090, that being the proportion of the $650,000 authorized by the legislature, which the work done bears to the expense of the whole work. In other words, the Commonwealth had made over-advances equal to $131,338, assuming $650,000 as the sum which the Commonwealth should furnish in the whole under the Act of 1860. And it is further shown that this statement is based upon the supposition that the work performed had been paid for, and so far as it went was a clear and unembarrassed security to the State for its advances, which in fact was not the case, for of the $175,000 appropriation of 1862, there is to be paid out towards these very expenditures the sum of $140,226.95, according to the returns made by the Commissioners, acting as auditors under that appropriation. Thus the sum total of our excess of advances becomes $271,564.95, on that piece of railroad, out of the $650,000 granted by the Act of 1860.

The following figures taken from the same statement, present a view of the amount advanced by the State on the same piece of road in excess of the amount actually thus far expended by the contractors upon the work.

Amount actually expended, ...		$485,731 19
Amount of the above yet to be paid by the State out of the $175,000 appropriation, . .		140,226 95
Amount expended by contractors, but not all paid for, as the $175,000 appropriated did not cover all the liabilities, ...		$345,504 24
Amount paid by the State on the first appropriation in sterling at $4.44 to the pound, ...	$50,172	
Difference between $4.44 and the real equivalent of the sterling in dollars, ...	5,311	
Amount paid under the $650,000 appropriation, ...	481,428	
		536,911 00
Amount advanced by Commonwealth more than went into the work, ...		$191,406 76

I congratulate the general court and the people, upon the rescue of the Commonwealth, and especially of this great experimental enterprise, from a position inconsistent with economical, safe or even possible success in piercing its mountain barrier.

I earnestly and respectfully invite your most candid and thoughtful consideration, not only of the specific facts and figures which elucidate or express the details of information bearing most immediately upon the work contemplated, but I also venture to commend to your deliberate judgment the arguments and reasoning drawn from liberal and enlightened views of public policy and of public economy, which finally lift this subject above all merely local interests or antagonisms, into the sphere of statesmanship. And having attentively watched the progress of the report of the Commissioners and the documents by which it is accompanied, through the press, I am prepared to give my own assent to the opinions, with the expression of which the Commissioners conclude their discussion :—

"By the time the tunnel can be completed, the public interest requiring it will have grown large enough to pay for the outlay. The impulse given to business by the new facility would soon fill up the new line, and make up the temporary loss felt by any other.

"Considering the large sum which the Commonwealth has already invested in this work, which must be sunk if it is not completed; the reasonable protection from loss which is offered by the other companies interested in the line; the more intimate relations it may promote between Massachusetts and the West; and the benefits which such an additional facility promises to the great interests of the city and State; we are of opinion that the work should be undertaken by the Commonwealth, and completed as early as it can be, with due regard to economy."

JOHN A. ANDREW.

Boston, March 12, 1863.

His Excellency John A. Andrew, *Governor of Massachusetts.*

Dear Sir,—With this I enclose to you the Report of the Commissioners of the Troy and Greenfield Railroad and Hoosac Tunnel.

I have the honor to be, most respectfully,
Your obedient servant,

J. W. BROOKS, *Chairman.*

BOSTON, March 12, 1863.

His Excellency JOHN A. ANDREW, *Governor of Massachusetts.*

Dear Sir,—I hand you enclosed herewith copy of a letter from myself to the presidents of the Fitchburg, and Vermont and Massachusetts Railroad Companies dated the 6th inst., and their reply to the same dated the 11th inst., concerning a lease of that part of the Troy and Greenfield Railroad east of the tunnel.

The interest at five per cent. upon the cost of completing that part of the road, as it shall be from time to time extended, to the close of the six years of the lease will amount to about $137,000.

The sum of the payments offered for the lease is $129,000.

The free use of the road and the concessions in rates of freight made to the State, will probably save a greater sum than the difference between the interest and offered rent.

The items of expense for which under the lease the State would be responsible, will result from defective construction if at all, and this correction would in any event be a proper charge to construction account.

Very respectfully, your obedient servant,

J. W. BROOKS, *Chairman.*

P. S. Supposing you might like this information at once, I send it to you before having an opportunity to confer with the other Commissioners.

BOSTON, March 6, 1863.

JOHN J. SWIFT, Esq., *President Fitchburg Railroad.*
ROBERT HALE, Esq., *President Vermont and Mass. Railroad.*

Gentlemen,—The estimate of the cost for completing the Troy and Greenfield Railroad from Greenfield to the east end of the Hoosac Tunnel is $497,060.

A small part of this, perhaps $40,000 or $50,000, need not be expended at present, but by letting some of the best trestle-works remain in the track until they begin to decay, a part of the permanent work can be delayed until the tunnel is near completion.

To enable the State to determine whether it will be wise to complete at once the Troy and Greenfield Railroad from Greenfield to the east end of the tunnel, or rather to the east end of the embankment, which is to be made from the tunnel excavation, we should like to know for what rent so much of the road can be leased for the next six years after it is ready for use, assuming that suitable depot buildings and side tracks are provided, and a turn-table and temporary engine-house at the tunnel end of the line, but no buildings at the Greenfield end.

Some stone abutments and other masonry, as well as bridges, will require to be built after the road is opened for use, the greater part most likely not for several years.

The lease should therefore be upon the condition that if the Commonwealth should provide trains for hauling such or any other materials destined for renewals or construction, no charge is to be made for the use of the track or for water for the engines; the fuel and all other expenses to be borne by the Commonwealth, and such trains to be kept out of the way of the regular trains and conform to the reasonable regulations of the lessee while upon the road.

If materials or tools are hauled by the lessee for renewals or construction, the freight upon the leased road to be charged to the Commonwealth at cost to the lessee.

It would be best to have the payment consist of a percentage of the gross earnings, the lessee guaranteeing that the payment shall amount to at least a stated or an increasing sum for each year.

If you will but consider that the rails, ties, buildings, bridges, fences and every thing are all fresh and new, that little if any renewals will occur during the lease, you will see that it can be worked very cheap, probably somewhere between half and two-thirds of the usual rate; and as the business will do the roads between Boston and Greenfield a great deal of good, bringing two or three times as much new earnings to each of them as it gets itself, you will see that whatever may be paid for it, the direct gain to the lessee, if it be one or both of those roads, will be very large.

A good price will also show faith in the line, of a practical character, and help the success of the whole thing very much.

Will you be kind enough to give this early attention and communicate with me?

Very respectfully your obedient servant,

J. W. BROOKS, *Chairman.*

BOSTON, March 11, 1863.

Dear Sir,—In reply to your communication of the 6th inst., we are authorized, by votes of our respective boards of directors, to make the following proposition to operate that portion of the Troy and Greenfield Railroad east of the Hoosac Tunnel, say between that point and Greenfield, for a period of six years from the time said road is put in complete condition to operate by the Commonwealth, including the necessary buildings and side tracks along the line, and a turn-table at the tunnel end of the line, but no buildings at the Greenfield end; it being understood that any and all damage which may arise to any of the masonry culverts or bridges, by freshets or otherwise, are to be made good by the Commonwealth, and that all slips of earth from either the cuts or the embankments, which amount to twenty cubic yards or more, shall be made good at the expense of the Commonwealth:

That, for the first year, we will pay as rent the sum of fifteen thousand dollars.

For the second year, the sum of eighteen thousand dollars.

For the third year, the sum of twenty-one thousand dollars.

And for the fourth, fifth, and sixth years, the sum of twenty-five thousand dollars each year.

And also permit the Commonwealth to run construction trains, to complete any unfinished portions of the work, and furnish water, free; all other expenses of such trains to be borne by the Commonwealth.

We also propose to transport all materials and tools for the construction of the tunnel, at two and one-half cents per ton per mile for first class, and two cents per ton per mile for second class freights, over the said leased road.

This proposition is made with the understanding that the Commonwealth shall proceed, with reasonable dispatch, to construct the tunnel.

Respectfully yours,

JOHN J. SWIFT, *President*,
In behalf of the Fitchburg R. R. Company.

ROBERT HALE, *President*,
In behalf of the Vermont and Mass. R. R. Company.

J. W. BROOKS, Esq., *Chairman Com's T. and G. R. R.*

BOSTON, March 13, 1863.

His Excellency JOHN A. ANDREW, *Governor of Massachusetts.*

Dear Sir,—Since handing you the report of the commissioners, I have put together some of the information which has been collected in the course of our investigation, which tends to show whether the State, under former appropriations, has or has not fully paid to the Troy and Greenfield Railroad Company such sums as that company was fairly entitled to receive for work performed. I have only had time to make that portion of the Statement which applies to the road between Greenfield and the tunnel. I may, in a few days, be able to submit a similar statement in regard to the payments on account of the tunnel. That referring to the road east of the tunnel, I hand you herewith.

I have not been able to confer with the other Commissioners in respect to this statement.

Very respectfully,
Your obedient servant,

J. W. BROOKS, *Chairman.*

Statement.

The Commissioners of the Troy and Greenfield Railroad and Hoosac Tunnel while investigating claims for labor, service and materials, under section third of the Act containing their authority, have necessarily examined the accounts of nearly the whole expenditure upon the construction of that part of the Troy and Greenfield Railroad between Greenfield and the tunnel.

About eighty-nine per cent. of this expenditure is from actual accounts, leaving but eleven per cent. to be estimated, and this is put at the highest rate which was paid for similar work in any of the accounts which have come before them.

The loan Act of 1859 after providing for certain advances upon the completion of two thousand feet of tunnel and a

portion of the road, provides that upon the completion of an additional one thousand feet of heading in the tunnel and grading three miles of the road near Greenfield, the further sum of $80,000 shall be advanced.

According to the prior provisions of this Act $50,000 of this was understood to be for the road, and $30,000 for the tunnel heading. Under this Act the sum of $50,172 in sterling at $4.44 to the pound, was advanced upon the road east of the tunnel.

The loan Act of 1860 provides for the further advance of $650,000 upon the road east of the tunnel, the deliveries to be pro rata with the progress of the work.

The amount of work done when the estimate was made upon which the $50,172 was paid, is certified by Mr. Harley, the engineer of the Troy and Greenfield Railroad Company and principal contractor, to have been as follows:—

Earth work, 48,264 cubic yards.

Loose rock, 500 cubic yards.

The highest price that could fairly be put upon this work would be sixteen cents per yard for the earth work and fifty cents per yard for the loose rock, at which rates the work upon which the $50,172 was advanced, amounted to $7,972.24.

Paper annexed and marked [A] gives very nearly the total expenditures of the principal contractors upon this part of the line, and the items of grading, bridging, masonry, and superstructure are as follows:

Grading, and such masonry as was done by the sub-contractors,	$251,000 43
Bridging, and such masonry as is not included above,	52,491 40
Iron,	134,392 27
Freight,	11,756 10
Ties,	7,795 25
Spike, chairs, and laying track, &c.,	5,612 45
Total amount expended,	$463,047 90
Deduct amount expended under $50,000 appropriation,	7,972 24
Amount expended under $650,000 appropriation,	$455,075 66

All of the expenditure for bridging and masonry is included in the above account, though much of it is so wholly unsuitable that it cannot be used, and the money paid for it is practically thrown away.

The cost of completing the grading, bridging, masonry and superstructure upon this part of the road, is as follows:—

Grading, ...		$150,499 80
Masonry, ...		142,361 00
Bridging, ...	$42,990 00	
Less materials on hand, . .	6,470 00	
		36,520 00
Superstructure, ...		65,660 00
Total amount required to be expended,		$395,040 80
Deduct expenditures required to complete the road more than would have been necessary had the work not been stopped, as follows:—		
Additional embankment for a small change in line and culvert masonry, .	$2,525 00	
Embankment washed away by Deerfield River, . . .	2,750 00	
		$5,275 00
Sum required to complete the road when the work stopped, ...		$389,765 80
Amount already expended under the last appropriation, ...		455,075 66
Including the cost of the worthless bridging, the whole amount expended and to be expended upon grading, masonry, bridging, and superstructure is, ...		$844,841 46
of which $53\frac{86}{100}$ per cent. had been done when the work stopped in July, 1861; a right therefore to $53\frac{86}{100}$ per cent. of the appropriation of $650,000 had at that time been earned, and this amounts to, . . .		$350,090 00

The advances made by the State on account of the work performed under the $650,000 appropriation have been as follows:

October 8, 1860, . . .	$64,090 00	
December 12, 1860, . .	112,190 00	
January 5, 1861, . . .	30,355 00	
February 18, 1861, . .	23,270 00	
March 7, 1861, . . .	19,890 00	
April 14, 1861, . . .	19,175 00	
May 7, 1861, . . .	61,555 00	
June 26, 1861, . . .	34,645 00	
July 9, 1861, . . .	90,064 00	
The advances to March 7, 1861, inclusive, were in sterling reckoned part at $4.44 and part at 4.44\frac{4}{10}$. The equivalent in dollars, for a pound sterling was at that time $4.91 in United States gold coin. The difference between 4.44\frac{4}{10}$ and $4.91 or over-payment is, . .	26,194 00	
Total amount advanced, ...		$481,428 00
Amount earned when the work stopped July 12, 1861, ...		350,090 00
Amount paid more than earned, . . .		$131,338 00

If the cost of the insufficient structures had been deducted, as they properly should be, from the cost of the work performed, thus leaving it at its true relative value to the whole cost of the work, the actual over-payments would be shown, and they would amount to a much larger sum.

This statement is thus far based upon the supposition that the work performed had been paid for, and so far as it went was a clear and unembarrassed security to the State for its advances. This, however, is not the case. Of the $175,000 appropriation of 1862, there is to be paid towards these very expenditures, for which credit has been given, the further sum of $140,226.95. This will swell the advances of the State

upon the work on which the $650,000 was to be loaned, up to the sum of $621,654.95; and the amount advanced more than the amount earned, up to $271,564.95; or, if no credit be given for the poor structures, the over-payments will be fairly stated, and will then amount to over $300,000.

Above is the statement referred to in my letter to Governor Andrew of the 12th March, 1863.

J. W. BROOKS, *Chairman.*

[A.]

Amount expended by H. Haupt & Co., upon the Troy and Greenfield Railroad, from Greenfield to the east end of the Hoosac Tunnel.—Distance, 30$\frac{15}{100}$ miles.

This portion of the road was subdivided into twenty-four sections by the constructing engineers, commencing at the bank of Green River, near Greenfield, and terminating at or near the east end of the tunnel.

These sections were sublet by H. Haupt & Co., as follows: and the estimates quoted are those of the resident engineer, H. Harley, upon which the sub-contractors were paid, and are doubtless correct.

Sections 1 and 2 were let to P. O. Keefe, and finished by him, for which he states that he received a compensation of $18,797.

Sections 3 and 4 were originally let to a firm of contractors, who abandoned the work when they ascertained that they were not to be allowed under their contract to fill in the ravines with earth, they alleging that this earthwork was held out to them as an inducement to bid upon the work at lower figures than they would otherwise have done.

As the principal contractors paid for the work already done, and finished these two sections themselves, the cost in detail cannot be accurately stated.

The final estimates of the contractor's engineer, Mr. Harley, made by him to W. S. Whitwell, State Engineer, July 1, 1861, for work done upon Sections 1, 2, 3, and 4, were as follows:—

78,318	cubic	yards	earth.
27,872	"	"	solid rock.
1,364	"	"	loose rock.
954	"	"	rip rap.
105	"	"	vertical wall.

To which may be affixed the following prices per cubic yard:—

Earth,	$0 20
Solid rock,	1 00
Loose,	50
Rip rap,	75
Vertical wall,	2 00

These prices were not part of the estimate made by Mr. Harley, but are affixed arbitrarily; but to be sure and get them high enough, they are put respectively at the highest prices paid for similar work to any sub-contractor on the line, and they of course include the same amount of profit to H. Haupt & Co. as realized by the sub-contractors on other portions of the road.

Sections 3 and 4, at the average prices paid, were among the best for a contractor to execute.

At the prices fixed, the amount for the work specified in the estimate quoted is	$45,115 50
Deducting from this the amount paid P. O. Keefe,	18,797 00
There remains,	$26,318 50

to represent the cost and profit of work done by H. Haupt & Co., on Sections 3 and 4.

The remaining sections were let to the following sub-contractors, and their final estimates include all that has been paid to them, as well as all that is still due, and are as follows:—

Amount paid to H. Haupt & Co. brought forward,	$45,115 50
Section 5. Wells & Perry, work done,	28,864 95
6. " " " "	10,886 58
7. " " " "	24,632 23
8. B. N. Farren, " "	17,115 19
9. " " " " "	9,206 46
10. P. Truesdell, " "	12,685 40
11. " " " "	12,031 92
12. Wells & Perry, " "	5,709 86
13. " " " "	3,829 72
14. " " " "	6,531 70
15. " " " "	6,177 75
16. " " " "	5,300 52
17. " " " "	6,190 92
18. B. N. Farren, " "	4,548 60
19. " " " " "	8,788 30
20. " " " " "	5,504 45

Section 21.	Wells & Perry,	work done, . . .		$11,085 69
22.	" "	" " . . .		10,605 65
23.	" "	" " . . .		5,140 00
24.	D. J. Cameron & Co.,	" " . . .		11,515 56
Total, ...				$251,466 95
Of which there remains unpaid, . .			$53,798 88	
in dispute, .			466 52	
				54,265 40
Amount of work actually paid for, ...				$197,201 55

Bridging and Masonry.

No estimates of these items appear to have been made by Mr. Harley other than as specified in the sub-contractor's estimates under the head of Grading.

The work of this description was under the charge of E. L. Childs, who kept the time-rolls and books appertaining to the work, from which these data are furnished.

Mr. Childs never had any adjustment of account with H. Haupt & Co., who are indebted to him for advances and superintendence, in settlement of which all bills and time-rolls relating to the work were submitted by Mr. Childs, for the purpose of substantiating his claim under the Act of 1862.

These bills aggregate, ...		$62,010 66
Materials undelivered and also unpaid for,	$8,976 58	
Disputed and doubtful, ...	541 68	
		9,518 26
		$52,492 40
Amount unpaid, ...		18,599 51
		$33,892 89

No profit either upon labor or material accrued to H. Haupt & Co. or E. L. Childs, in this item.

Iron.

The Rensselaer Iron Company claim to have delivered to H. Haupt & Co. 13,275 bars of iron, weighing 2,671 tons, 1 cwt., 3 qrs., 24 lbs., at $50, . . .	$133,554 91
Which number of bars have been delivered by the Connecticut River Railroad Company at Greenfield to H. Haupt & Co. or his agents.	
They also have delivered two patent frogs, . . .	67 58
And paid freight on railroad iron to Greenbush, . .	769 78

Making an aggregate of		$134,392 27
Upon which there has been paid		70,921 98
Leaving a balance unpaid of		$63,470 29

Freight.

The freight bill of the Connecticut River Railroad Company, on 6,297 bars iron, amounts to $5,312.62; at the same rate the 6,978 remaining bars delivered by them would cost,		$5,887 16
Bill rendered by Connecticut River Railroad Company,		5,368 94
Estimated freight on other deliveries,		500 00
Whole amount expended,		$11,756 10
Of which there has been paid,		6,387 16
Amount still due,		$5,368 94

Ties.

The number of ties found upon the road is 31,181—putting the price at twenty-five cents, the highest price claimed of the Commissioners on the line, and the amount is,		$7,795 25
Of this there is unpaid,		3,148 65
Amount expended by H. Haupt & Co.,		$4,646 60

Miscellaneous.

There are outstanding bills as follows :—

Legal expenses,	$335 25	
Services,	1,446 93	
Labor,	90 90	
Reconstructing highways,	701 62	
Board bills, laborers,	97 59	
Rent,	10 00	
		2,682 29
Total due,		$2,682 29

Chairs, Track, &c.

A. R. Fields' bill, iron work,	$2,112 45	
Less balance unpaid,	336 79	
		$1,775 66
200 kegs spike, delivered at $5,		1,000 00
Laying five miles track, at $500,		2,500 00
Total expended by H. Haupt & Co.,		$5,275 66

[A.]

RECAPITULATION.

Items of Expenditure.	Totals.	Amount unpaid.	Amount paid.
Grading and such masonry as was done by contractors,	$251,000 43	$53,798 88	$197,201 55
Bridging and such masonry as is not included above,	52,492 40	18,599 51	33,892 89
Iron,	134,392 27	63,470 29	70,921 98
Freight,	11,756 10	5,368 94	6,387 16
Ties,	7,795 25	3,148 65	4,646 60
Legal expenses,	335 25	335 25	–
Services,	1,446 93	1,446 93	–
Labor,	90 90	90 90	–
Highways,	701 62	701 62	–
Board bills of men,	97 59	97 59	–
Rent,	10 00	10 00	–
Spike, chairs, &c.,	5,612 45	336 79	5,275 66
			$318,325 84
Add for superintendence and contingencies,	20,000 00	–	20,000 00
Totals,	$485,731 19	$147,405 35	$338,325 84

REPORT

OF THE

COMMISSIONERS

UPON THE

TROY AND GREENFIELD RAILROAD

AND

HOOSAC TUNNEL,

TO

HIS EXCELLENCY THE GOVERNOR,

AND THE

HONORABLE THE EXECUTIVE COUNCIL

OF THE

State of Massachusetts.

FEBRUARY 28, 1863.

BOSTON:
WRIGHT & POTTER, STATE PRINTERS,
4 SPRING LANE.
1863.

INDEX.

PLATES.

(At end of Commissioners' Report.)

APPENDIX.

COMMISSIONERS' REPORT.

To His Excellency The Governor,
and the Honorable The Executive Council,
of the Commonwealth of Massachusetts.

The Commissioners, appointed under the provisions of chapter 156 of the Acts of 1862, "providing for the more speedy completion of the Troy and Greenfield Railroad and Hoosac Tunnel," entered upon their duties immediately after their appointment, in May last, and now beg leave to report their doings and the result of their investigations.

In making this Report, they do not propose to discuss the various branches of the subject in the order in which they are mentioned in the law under which they are acting, but rather the order in which an inquirer would more naturally take up the subject for consideration.

For obvious reasons the investigation of claims for labor, service, materials, and land damages was not commenced until that possession of the property contemplated by the law had been obtained by the Commissioners; since which they have given to this and the other duties of their commission continued attention.

POSSESSION.

Upon the request of the Commissioners, the Troy & Greenfield Railroad Company, acting under authority of section second of the Act before referred to, surrendered to the Commonwealth the road and property of the Company, such surrender having been authorized by the Board of Directors by the following votes, passed on the 18th August, 1862: —

Voted, That the Directors of the Troy & Greenfield Railroad Company hereby instruct the President to surrender to the Commonwealth of Massachusetts, under the several mortgages held by said Commonwealth, all the property of said corporation.

Voted, That the clerk is hereby ordered to call a meeting of the corporation at Greenfield, on the second day of September next, at 4 o'clock, P. M., to see whether the stockholders will ratify and confirm the vote of the Directors, whereby they instructed the President to surrender to the Commonwealth of Massachusetts, under the several mortgages held by said Commonwealth, all the property of said corporation.

At a meeting of stockholders, called in pursuance of the foregoing order, and held at Greenfield on the 2d day of September, 1862, the action of the Directors in the premises was ratified by the following vote: —

Voted, That the corporation hereby ratify and confirm the vote of the Directors, whereby they instructed the President to surrender to the Commonwealth of Massachusetts, under the several mortgages held by said Commonwealth, all the property of the said corporation, and the President is hereby authorized and instructed to execute all instruments proper to perfect said surrender.

On the 4th day of September copies of these votes were served upon the Commissioners.

On the same day, September 4, 1862, the Commissioners took quiet and peaceable possession of the road and property in each of the towns in which it is situated.

At the same time the Treasurer of the Commonwealth, for default under the mortgages, took a similar possession.

The fact of taking possession under each of the several mortgages has been recorded in the counties in which the road and property is situated.

In accordance with the votes of the Company, its President executed a surrender of the property to the Commonwealth by an instrument of which the following is a copy: —

Know all men by these presents, that the Troy & Greenfield Railroad Company, a corporation duly established by law, doth by these presents

Surrender unto the Commonwealth of Massachusetts, under the several mortgages held by said Commonwealth, all the property of said corporation, real, personal, or mixed, wherever situate, subject only to the right of redemption, under the second section of chapter one hundred and fifty-six, of the Acts of 1862.

To have and to hold to the said Commonwealth and its assigns forever.

In witness whereof, the said Troy & Greenfield Railroad Company, by Alvah Crocker, the President thereof, thereto duly authorized and empowered by the votes of said corporation and the Directors thereof, copies of which are hereto annexed, hath affixed the seal and subscribed the name of said corporation, this thirteenth day of October, A. D. 1862.

Signed,

TROY & GREENFIELD RAILROAD COMPANY.

By ALVAH CROCKER. [SEAL.]

Regarding it as possible that some right might exist upon which a question could be raised by the principal

contractors adverse to the possession of the property by the Commissioners, the following letter was addressed to them:—

BOSTON, September 23, 1862.

H. HAUPT & Co.

Gents., — I do not know that you claim any right against the property of the Troy & Greenfield Railroad Company, adverse to the possession lately taken by the Commissioners.

As questions in this regard may be raised, and that the contemplated possession may be so full and unquestioned that more money may properly be expended upon it by the State, I have to request, on the part of the Commissioners, that you will execute and acknowledge the paper which will be handed you herewith by Mr. Rice.

Very respectfully yours,

J. W. BROOKS, *Chairman.*

The release as first executed was so altered as to be of no apparent value to the Commonwealth, and another release was afterwards delivered to the Commissioners, of which the following is a copy:—

Know all men by these presents, that we, Herman Haupt and Henry Cartwright, partners, under the name, style, and firm of H. Haupt & Co., hereby consent and agree to the possession that has been taken by the Commissioners appointed according to the provisions of "an Act providing for the more speedy completion of the Troy & Greenfield Railroad and Hoosac Tunnel," approved April 28th, 1862, and by the Commonwealth of Massachusetts, by said Commissioners and the Treasurer thereof, under the one hundred and fifty-sixth chapter of the Statutes of 1862.

And in consideration of all sums which the Commonwealth will be obliged to expend under the said Act, do hereby release all our right, title, and interest in and to said railroad, and all the property of said Company, in such manner, and to such extent, as to give to the Commonwealth priority of title, possession, and use over and above us, or either of us, until after all debts and claims now existing, or which

may hereafter arise, in favor of said Commonwealth against said Troy & Greenfield Railroad, shall have been fully paid and satisfied; but, nevertheless, reserving all rights or claims which we, or either of us, may have against said Commonwealth, for the injustice which by said Act has been done to us, or either of us, in consequence of which we expressly claim and reserve the right to petition any future Legislature for redress of grievances.

Witness our hands and seals this twenty-third day of December, A. D. 1862.

Witness,
George L. Full to H. H. — H. HAUPT. [SEAL.]
L. Y. Walraven. — HENRY CARTWRIGHT. [SEAL.]

In justice to Mr. Haupt, it may be proper that we should insert the following letter, subsequently received from him, though it is not supposed by us to have any legal or equitable significance.

Boston, January 8, 1862.

J. W. Brooks, Esq., Chairman of Commissioners T. & G. R. R.

Sir, — Although aware of the fact that you were transcending the authority vested in the Commissioners of the Troy & Greenfield Railroad by the Act of 1862, and that you were assuming the powers of legislators by imposing conditions not required by said Act; yet, to mitigate the intensity of individual suffering and remove all pretexts for longer withholding the disbursements of the appropriation for the payment of those who had furnished materials and performed services, I was induced to execute certain papers relinquishing certain individual rights. As you have failed to the present time to make such payments, and have given no consideration whatever for the concessions made in said instruments,

I hereby notify you that if said payments are not made on or before the first day of February next, said papers will be withdrawn, and will not be recognized by me as of any binding force or obligation.

Yours very respectfully,

H. HAUPT.

TITLE.

The first bond and mortgage given by the Company to the Commonwealth is as follows: —

Know all men by these presents, that the Troy & Greenfield Railroad Company is held and stands firmly bound unto the Commonwealth of Massachusetts, in the full and just sum of four million dollars, to the payment of which said sum, well and truly to be made, the Troy & Greenfield Railroad Company binds itself and its successors unto the Commonwealth of Massachusetts, and its assigns firmly by these presents.

In witness whereof the Troy & Greenfield Railroad Company has caused its seal to be hereunto affixed, and these presents to be signed by a Committee and its Treasurer this twenty-eighth day of July, one thousand eight hundred and fifty-five (28 July, A. D. 1855).

The condition of this obligation is such that, whereas, in and by an Act of the Commonwealth of Massachusetts, approved on the fifth day of April, A. D. eighteen hundred and fifty-four, entitled "an Act, authorizing a loan of the State credit, to enable the Troy & Greenfield Railroad Company to construct the Hoosac Tunnel," it is enacted as follows: —

For the Act of April 5, 1854, see "Statutes, 1854, chapter 226," the main points of which are as follows: —

Sect. 1 provides for the issue of $2,000,000 of 5 per cent. coupon scrip, payable in Boston or London, as the Company may elect, "for the purpose of enabling the said Company to construct a tunnel under and through the Hoosac Mountain, in some place between the 'Great Bend' in Deerfield, being in the town of Florida, at the base of the Hoosac Mountain, on the east, and the western side of the mountain, near the east end of the village of North Adams, on the west."

Sect. 2 gives the terms in detail upon which the scrip shall be issued.

Sects. 3 and 4 relate to sinking fund, and require ten per cent. on the amount of each issue of scrip to be paid into a sinking fund, and after the road is opened, $25,000 per annum.

Sect. 5 requires the Company to accept the Act, and mortgage its railroad income, franchise, and property to the State, as security for the loan of scrip.

Sect. 6 requires the Company to assign the interest it has, or may hereafter obtain, in the "Southern Vermont Railroad Company."

Sect. 7 allows the Company to alter the location of the road before making the mortgage, and within one year, provided the Tunnel be located and built within the limits prescribed by this Act.

Sects. 8 and 9 extend time for completing railroad, and provide for two State Directors.

Now, therefore, the condition of the above obligation is such, that if the said Troy & Greenfield Railroad Company shall comply with the requisitions of this Act, and shall faithfully expend the proceeds of said scrip in the construction of their road as provided in said Act, and shall indemnify and save harmless the Commonwealth from all loss or inconvenience on account of said scrip or certificates of debt, and if said corporation shall and will pay the principal sum of said scrip or certificates which may be delivered to their treasurer punctually, when the same shall become due, or such part thereof as the sinking fund may be insufficient to pay, and the interest thereon semi-annually, as the same shall fall due, then, and on the above conditions, the foregoing obligation shall be void and of no effect, but shall otherwise remain in full force and virtue.

OTIS CLAPP,
WM. A. GALBRAITH,
WENDELL T. DAVIS, *Treasurer.*

Executed and delivered in presence of

JOHN L. ANDREWS,
J. H. CHOATE.

Know all men by these presents, that the Troy & Greenfield Railroad Company, in consideration of the sum of two millions of dollars, paid, or to be paid, by the Commonwealth of Massachusetts, according to the provisions of a certain Act of the Commonwealth, approved on the fifth day of April, A. D. 1854, entitled "an Act authorizing the loan of the State credit, to enable the Troy & Greenfield Railroad Company to construct the Hoosac Tunnel," does hereby give, grant, bargain, sell, and convey unto the Commonwealth of Massachusetts the entire railroad of said corporation and its franchises, income, and property.

Also, there is hereby assigned and conveyed all the interest which the said Troy & Greenfield Railroad Company now has, or may or shall at any time hereafter have or obtain, in the Southern Vermont Railroad Company. The intent and meaning hereof being that this conveyance shall, as against any claims or incumbrances to which the said road, franchise, or property may be hereafter subjected, operate to cover and bind any and all lands included within the location of the said road, the title to which, or the easement upon which shall be hereafter acquired, and any and all additions which shall be made hereafter to said road by labor, materials, or otherwise, and any lands hereafter purchased and appropriated for depots for said road, or any buildings or fixtures placed thereon, and also any engines, cars, or other apparatus which may be placed on said road, or procured therefor, as fully as if the said road had been completed, and all the property acquired and owned by said corporation at the time of the execution of this conveyance, together with all the interest the said corporation now has, or may or shall at any time hereafter obtain or have, in the Southern Vermont Railroad Company.

Provided, that this conveyance shall not be construed to include or affect any personal property which shall have been sold by said corporation to a bona fide purchaser before the Commonwealth shall take possession thereof under this conveyance.

To have and to hold the said entire railroad income, property, and franchise of the said Troy & Greenfield Railroad Company, and such interest as said company now has or may or shall hereafter have or obtain, in the Southern Vermont Railroad Company, to the Commonwealth of Massachusetts, and its assigns, to their use and behoof forever.

Provided, nevertheless, that whereas in and by the aforesaid Act of the Commonwealth of Massachusetts, the Treasurer of the Commonwealth is authorized and instructed to issue scrip, or certificates of debt, in the name and behalf of the Commonwealth, and under his signature,

and the seal of the Commonwealth, for the sum of two million dollars, which may be expressed in the currency of Great Britain, and may be payable to the bearer thereof in London, and bearing an interest of five per cent. per annum, payable semi-annually in London, on the first day of April and October, or the said scrip may be issued in Federal currency, payable in Boston, as the Directors of the Troy & Greenfield Railroad Company shall elect, when they apply for each and every issue of said scrip, with warrants for the interest attached thereto, signed by the Treasurer, which scrip or certificates in the currency of Great Britain, shall be redeemable in London, and those in the Federal currency, in Boston, at the end of thirty years from the date hereof, and shall be countersigned by the Governor of the Commonwealth, and be deemed a pledge of the faith and credit of the Commonwealth for the redemption thereof; and that the Treasurer of the Commonwealth shall, under the conditions thereinafter provided, deliver the same to the Treasurer of the Troy & Greenfield Railroad Company, for the purpose of enabling the said company to construct the Hoosac Tunnel.

And whereas, provision is made in said Act for the creation of a sinking fund for the future purchase or final redemption of said scrip; and,

Whereas, it is also provided that no part of said scrip shall be delivered to the treasurer of said corporation until said corporation shall have executed to the Commonwealth a bond in such form as was prescribed by the Attorney-General on the issuing of the scrip to the Western Railroad Corporation, conditioned that said Troy & Greenfield Railroad Company shall comply with the provisions of said Act, and shall faithfully expend the proceeds of said scrip, as therein provided, and shall indemnify and save harmless the Commonwealth from all loss or inconvenience on account of said scrip, and shall well and truly pay the principal sum of said scrip punctually when the same shall become due and payable, or such part as the sinking fund aforesaid shall be insufficient to pay, and the interest thereon semi-annually, as the same shall fall due, and shall also assign to the Commonwealth, by suitable instrument or instruments, of the same form with that, or those prepared by the Attorney-General on the issuing of scrip to the Western Railroad Corporation, their entire railroad, with its income, and all the franchise and property to them belonging, as a pledge or mortgage, to secure the performance of all the conditions of said bond, and also to assign all the interest said Troy & Greenfield Railroad Company now has, or may at any time hereafter obtain, in the Southern Vermont Railroad Company; and,

Whereas, the Troy & Greenfield Railroad Company has executed to the Commonwealth the bond aforesaid, bearing even date herewith; now,

Therefore, if the said Troy & Greenfield Railroad Company shall well and truly keep and perform the conditions of said bond, according to their true meaning and intent, then this deed, and the bond aforesaid, shall both be void, but otherwise, shall remain in full force and virtue.

And provided, also, that the Commonwealth shall not take possession of said pledged or mortgaged property unless for a substantial breach of some condition of said bond. And the Troy & Greenfield Railroad Company, for the consideration aforesaid, covenants with the Commonwealth of Massachusetts and its assigns, that the said corporation will, at any time or times hereafter, on reasonable notice and request, execute any other and further instrument or assurance that the Attorney-General of the Commonwealth, for the time being, shall advise to be necessary and proper to secure the Commonwealth, or its assigns, according to the true intent and purpose of the Act aforesaid.

In witness whereof, the Troy & Greenfield Railroad Company has caused its seal to be hereto affixed, and these presents to be signed in its behalf, by Otis Clapp, Wm. A. Galbraith, and Wendell T. Davis, a committee duly authorized and appointed for that purpose, and also to be countersigned by said Wendell T. Davis, the Treasurer of said corporation, this twenty-eighth day of July, A. D. eighteen hundred and fifty-five.

OTIS CLAPP,
WM. A. GALBRAITH,
WENDELL T. DAVIS, *Treasurer.*

Signed in presence of
J. L. Andrews,
J. H. Choate.

Subsequent to the execution of this mortgage the Company changed the location of their road, excepting most of that part lying west of North Adams, and, so far as the mortgage depended upon the location, the security of the State was endangered.

It may be possible that the Act contained in chap. 117, Acts 1859, by changing the terms of the loan, also affected the security of the State. As, however, all the loan acts related to the same two millions of dollars, and the mortgage clearly intended to cover the whole property of the Company, the mere change in the terms of the loan, in favor of the Company, did not, probably, weaken the security.

In this Act, sections 1, 2, and 3 modify the terms upon which the State scrip may be issued to the Company.

Sect. 4 provides that the preceding section shall be substituted for sections 2 and 3 of chapter 226, Acts 1854, " which are hereby repealed."

Sect. 5 extends time for completing the road.

Sect. 6 relates to stock subscriptions.

Sect. 7 requires the Act to be accepted by the Company.

In 1860 the terms of the loan were again modified, by an Act contained in chapter 202 of the Acts of 1860.

Sect. 1 requires the Company to make and file a location of their line forthwith, and limits the grade and curvature as compared with the Fitchburg, and Vermont & Massachusetts Railroads.

Sect. 2 divides the new issues of scrip between the unfinished Railroad and the Tunnel, assigning a fixed amount to each; no more to be issued till the Company assent to the Act; locates its line, and makes a further mortgage to the State, and provides that said bond and mortgage, and other assurances, and all bonds, mortgages, or other assurances heretofore made to the Commonwealth by said Company, shall have priority to, and be preferred before, any and all attachments or levies on execution heretofore or hereafter made.

Sect. 3 provides for a State engineer, specifies his

duties, regulates the delivery of scrip, fixes the character of the work, and gives the Governor and Council supervision of it.

Sect. 4 relates to payment on account of interest and sinking fund.

Sects. 5, 6, and 7 relate to crossing highways (State, town, and city), Directors, and capital stock.

Sect. 8 authorizes purchase of Southern Vermont Railroad, and provides $200,000 of scrip to pay for it, fixing the terms of payment.

Sect. 9 repeals inconsistent Acts, provided such repeal, nor any thing in this Act, shall impair the security which the Commonwealth has, or may hereafter have, by force of the bond and mortgage now held by the State on the franchise, railroad, and property of the Company.

Under this Act the Company made to the State the following mortgage, dated July 6, 1860: —

Know all men by these presents, that, whereas, in and by an Act of the General Court of the Commonwealth of Massachusetts, approved by the Governor on the fourth day of April last past, entitled "an Act in addition to an act authorizing a loan of the State credit, to enable the Troy & Greenfield Railroad Company to construct the Hoosac Tunnel," the said Railroad Company are required to file a location of their entire road and tunnel in the manner and form in said Act prescribed; and, whereas, it is also provided in said Act, that no delivery of the State scrip, heretofore authorized to be delivered to said Company, shall be made until such location shall have been duly made, and said Company shall have executed to the Commonwealth such further bond and mortgage, or other assurances of title, on their franchise, railroad, or other property, as the Attorney-General shall prescribe, for the further security of the Commonwealth; and, whereas, the said Company have fully complied with all the requirements of said Act, in relation to the making and filing of said location;

Now, therefore, the said Troy & Greenfield Railroad Company, a corporation established by law, in consideration of two million

dollars, paid, or to be paid, by the Commonwealth of Massachusetts, according to the provisions of the several acts relating thereto, does hereby give, grant, bargain, sell, convey and confirm, unto the said Commonwealth of Massachusetts, the entire railroad of said corporation, and all its franchises and property whatsoever; and doth hereby ratify and confirm all bonds, mortgages, and other conveyances and assurances heretofore executed and delivered by said corporation to said Commonwealth; the intent and meaning hereof being to convey and confirm, as aforesaid, to said Commonwealth, all lands, buildings, and tenements, and all interests and easements therein, that said corporation now has, or hereafter may acquire, within the limits of the location, made and filed as aforesaid, and to confirm all former conveyances, bonds, and mortgages, heretofore made, as aforesaid. Provided, that this conveyance shall not be construed to include, or affect, any personal property, which shall have been sold by said corporation to a bona fide purchaser, before the Commonwealth shall take possession thereof, under this or some other conveyance;

To have, and to hold, the franchises, property, and premises, hereby conveyed to the said Commonwealth and its assigns, to their use and behoof forever.

Provided, nevertheless, that if the said Troy & Greenfield Railroad Company shall well and truly do and perform, all and every, the obligations, duties, covenants, and agreements, by them heretofore undertaken, covenanted, and agreed to be done and performed, in the several bonds, mortgages, and conveyances, heretofore made and delivered by them to said Commonwealth, and shall, also, well and truly do, perform, and observe, all the terms, conditions, and requirements of the several Acts of the General Court, heretofore passed, or that may be hereafter passed, relating to said railroad and tunnel, and to the loan of the State credit in aid thereof, and shall also execute and deliver to the said Commonwealth, or its assigns, any other or further assurances, conveyances, or instruments, that the Attorney General of said Commonwealth for the time being shall advise to be necessary to secure the Commonwealth, or its assigns, according to the true intent and purpose of said several acts, upon reasonable notice, then this deed shall be void, otherwise, in full force and virtue.

In witness whereof, the said Troy & Greenfield Railroad Company has caused its corporate seal to be hereto affixed, and these presents to be signed by D. N. Carpenter, H. Haupt, and E. G. Lamson, in its behalf, a committee duly authorized and appointed for that purpose, and also to be countersigned by Wendell T. Davis,

its Treasurer, this sixth day of July, in the year one thousand eight hundred and sixty.

Signed, D. N. CARPENTER,
H. HAUPT, [SEAL.]
E. G. LAMSON,

Countersigned by
WENDELL T. DAVIS, *Treasurer.*
Acknowledged July 9, 1860.

This mortgage, as qualified by the clause heretofore quoted from sect. 2 of chap. 202, Acts 1860, though not perhaps as full as could be desired, appears a reasonable compliance with the act requiring it.

On the 5th of April, 1862, another mortgage was given to the State, as follows:—

Know all men by these presents, that the Troy & Greenfield Railroad Company, a corporation established by law, in consideration of the sum of one dollar, and other valuable consideration to the said corporation, paid by the Commonwealth of Massachusetts, the receipt whereof is hereby acknowledged, does hereby give, grant, bargain, sell, convey and confirm, to the said Commonwealth of Massachusetts, all the franchises and property whatsoever, real, personal, and mixed, of said Troy & Greenfield Railroad Company;

To have and to hold the said franchises and property, real, personal, and mixed, above granted to the said Commonwealth, and its assigns, to their use and behoof, forever.

Provided, nevertheless, that if the said Troy & Greenfield Railroad Company shall well, and truly do and perform, all and every, the obligations, duties, covenants, and agreements, by them heretofore undertaken, covenanted, and agreed to be done and performed, in the several bonds, mortgages, and conveyances, heretofore made and delivered by them to said Cammonwealth, and shall also well and truly do, and perform, and observe, all the terms, conditions, and requirements, of the several Acts of the General Court of said Commonwealth heretofore passed, then this deed shall be void, otherwise, in full force and virtue.

In witness whereof, the said Troy & Greenfield Railroad Company has caused its corporate seal to be hereto affixed, and these

presents to be signed by Alvah Crocker, President of said corporation, thereto duly authorized this fifth day of April, eighteen hundred and sixty-two.

Signed, A. CROCKER, *President.*

Acknowledged April 7, 1862.

Immediately after the date of the first mortgage to the State a second mortgage was made by the Company to other parties, to secure the payment of $900,000 of bonds, as follows: —

Know all men by these presents, that, whereas, the Troy & Greenfield Railroad Company, a corporation established in the Commonwealth of Massachusetts, have heretofore entered into an agreement with Edward W. Serrell, of the City, County, and State of New York, civil engineer, for the construction of the Troy & Greenfield Railroad, and by the terms of a certain contract between them and its supplements, it is provided, among other things, that said Serrell shall receive from said corporation, in part compensation for the work of constructing their railroad, nine hundred bonds of said corporation, for the sum of one thousand dollars each, bearing date the 30th day of July, A. D. one thousand eight hundred and fifty-five, and are all payable thirty years thereafter, with interest at the rate of six per cent., payable at Boston, in the County of Suffolk and Commonwealth aforesaid; and, whereas, at a meeting of the stockholders of said corporation, holden at Greenfield, in said Commonwealth, on the twenty-sixth day of July current, it was voted "that the Board of Directors of such corporation, by themselves, or by a committee duly authorized and appointed for that purpose, should execute such mortgage or other instrument, to be countersigned by their Treasurer, as might be necessary, to secure the payment of said bonds and the interest thereon;" and, whereas, afterwards, at a meeting of the Board of Directors of said corporation, at said Greenfield, held on the same day, Otis Clapp and William A. Galbraith were, by a vote of said Board of Directors, duly appointed a committee, with said Treasurer to countersign, to carry out the purpose of the vote of said stockholders above specified, and to make and execute in behalf of said corporation such mortgage, or other instrument as might be necessary to secure the payment of the principal and interest of the said bonds

when the same shall respectively fall due, and to convey in mortgage to three Trustees, for the said purpose, the entire railroad of said corporation, with its franchise and fixtures, cars, engines, and other property which now belong to it, and shall be hereafter acquired by it, subject only to the prior lien of the Commonwealth of Massachusetts, under a mortgage, made under the provisions of the Act of May 5th, 1854, to secure to it the amount of an issue of two millions of dollars of State bonds, with interest at five per cent., which said Commonwealth is to issue to said Corporation, to enable them to construct the Hoosac Tunnel; and, whereas, Jerome V. C. Smith, Paul Adams, and John G. Davis, all of said Boston, have been duly selected Trustees for the holders of said Serrell bonds.

Now, therefore, the said Troy & Greenfield Railroad Company, in consideration of the premises, and of one dollar, and other adequate considerations to them paid, by Jerome V. C. Smith, Paul Adams, and John G. Davis, all of Boston, in said Commonwealth, gentlemen, the receipt whereof is hereby acknowledged, do hereby grant, bargain, assign, and convey unto them, the said Smith, Adams, and Davis, the entire railroad of said corporation, lying in the counties of Franklin and Berkshire, in said, Commonwealth, and extending from a point near the line between the towns of Greenfield and Deerfield, in said Franklin, to the State line in Williamstown, in said Berkshire, together with its franchise, real estate, fixtures, stations, buildings, cars, engines, equipage, tools, and other property which now belong to, or shall hereafter be acquired by, said corporation, subject only to the prior mortgage to the said Commonwealth above specified.

To have and to hold the same to them, the said Jerome V. C. Smith, Paul Adams, and John G. Davis, and the survivor of them, his heirs and assigns forever,

Provided, nevertheless, that if the said corporation, their successors or assigns, shall duly pay the interest and principal of said bonds, which shall be issued under the contract with said Serrell, as the same shall become due, then this deed shall become void.

And provided, further, that the said Trustees shall not hereby incur any liability, except that each of them shall be liable for his gross neglect and wilful default.

And provided, further, that in case either of said Trustees shall die or resign, the survivors are hereby empowered to fill vacancies, and by any instrument in writing to designate a successor, and to associate him with them in the same trusts, and vest in him jointly with them the mortgaged property in trust as aforesaid. And the new Trustees

may in the same manner, from time to time, fill all vacancies, and continue the trust.

And provided further, that in case it shall become necessary or expedient to make any change or modification of this instrument, in order to secure to the State its prior lien for its loan of two millions of dollars, and interest herein before referred to, said Trustees shall have full power to permit such change or modification, and the same may be made by such corporation, in such manner, however, as to preserve the rights of the bondholders under this instrument to a lien upon the mortgaged premises, second only to that of the State, for such two millions of dollars and interest, otherwise it shall be and remain in full force and virtue.

Provided, however, that neither said Trustees, their successors or assigns, shall take possession of the mortgaged premises except for some substantial breach of the conditions of said Serrell bonds.

In witness whereof, the said Troy & Greenfield Railroad Company, by Otis Clapp, William A. Galbraith, and Wendell T. Davis, their Treasurer to countersign, a committee duly appointed by the Board of Directors of said Company, as within mentioned, have caused these presents to be executed, and their corporate seal to be affixed, this thirtieth day of July, A. D. one thousand eight hundred and fifty-five.

Signed,

OTIS CLAPP,
WM. A. GALBRAITH,
WENDELL T. DAVIS, *Treasurer.*

Acknowledged, Aug. 18, 1855.

The statute in relation to railroad mortgages, chapter 286, Acts 1854, authorizes the issue of bonds to fund a debt or borrow money. The issue sought to be secured by this mortgage was not for either of these purposes. but by its terms to pay a contractor for work yet to be done.

The statute restricts the amount to not exceeding the amount of stock paid up, whereas the amount of bonds in this case was many fold the amount of paid up stock.

The statute provides that the bonds issued shall be

for a period not exceeding twenty years. These are made for thirty years.

The franchise cannot be sold or mortgaged without permission from the Legislature, which in this case has not been given.

In Massachusetts, such a mortgage cannot attach to after-acquired property. If the first mortgage to the State sustained any injury, from changes made in the location of the line subsequent to its execution, the second mortgage has been equally damaged.

From these considerations it is apparent that whether the mortgage was intended to be made in pursuance of the statute above quoted or otherwise, as against bona fide creditors, it is radically defective, and for these and other reasons has probably but little if any value, even as against the Company.

Southern Vermont Railroad.

The Southern Vermont Railroad was leased to the Troy & Boston Railroad Company, by a lease dated November 26, 1856, but not executed until a later date, certainly not before January 2, 1857. It was recorded March 10, 1858.

This lease is for the term of the charter of the corporation, and for any renewals of the same: it is therefore perpetual.

In this lease are the following clauses: —

"It being understood and allowed, however, that until the completion of the Hoosac Tunnel, timber abutments for bridges on each bank of the Hoosac River may be used, and that a six degree curve may be used to avoid the thorough cut at or near the State line of Massachusetts at the eastern end of the road."

"It is also agreed that the temporary structures and location agreed to in this contract shall be changed and reconstructed in a permanent and satisfactory manner, at or before the time of completion of the Hoosac Tunnel, and if not so completed within one year from that time, the Troy & Boston Company shall have the right to make the alterations and reserve three thousand dollars per annum from the pay to be applied to this object until completed.

"The said road and fixtures to be kept in good repair at the expense of the said party of the second part during the continuance of the lease, except that in case of casualty happening to the temporary structures herein before named, then and in that case the expense of repairs shall be borne by said Southern Vermont Railroad Company."

The sum to be paid for the use of the road is twelve thousand dollars per annum, subject to a reduction for the cost of repairing temporary structures in case of casualty, and at or before the completion of the Hoosac Tunnel, subject to additional reduction of three thousand dollars per annum for some years, or the alternative of an increased expenditure on capital account, to make permanent, certain temporary works, as explained in the clauses quoted above.

On the 21st day of April, 1860, the Southern Vermont Railroad was sold to the Troy & Greenfield Railroad Company, the latter Company having been authorized to make the purchase by the Act contained in chapter 202 of the Acts of 1860.

To make this purchase the State advanced to the Troy & Greenfield Railroad Company two hundred thousand dollars, taking as security a mortgage upon the property.

For the lease of the Southern Vermont Railroad, and its sale to the Troy & Greenfield Railroad Company, and mortgage to the Commonwealth, we beg to refer to the Report of the Attorney-General, in Senate Doc. No. 157, for 1862.

This piece of road was an easy line to build, and probably did not cost above from $110,000 to $125,000 to construct.

The object in paying so large a profit, or, in fact, the object in buying the road at all, is not apparent. It having been permanently leased to another company, no authority or control whatever was acquired over it by the purchase. As long as the rent is paid, it is as independent of the present owner, as the New York Central, or the London and Birmingham Roads.

Troy and Greenfield Lease to Troy and Boston Railroad Company.

That part of the Troy & Greenfield Railroad lying between North Adams and the Vermont State line, about 6 80-100 miles in length, is operated by the Troy & Boston Railroad Company, under a lease, of which the following is a copy: —

These Articles of Agreement, made this 21st day of November, A. D. 1856, by and between the Troy & Greenfield Railroad Company of Massachusetts, of the one part, and the Troy & Boston Railroad Company of the State of New York, party of the second part:

Whereas, the said Troy & Greenfield Railroad Company have contracted with H. Haupt & Co. for the building of their railroad from Greenfield to the State line, at or near Williamstown, including the Hoosac Tunnel; and whereas, that portion of said road lying between the Pittsfield and North Adams Railroad depot, in North Adams village, and the State line of Vermont, is expected to be shortly finished, and it is desirable that the same shall be brought into use; now, therefore, these presents witness, that the said Troy & Greenfield Railroad Company does hereby agree to let and lease unto said Troy & Boston Railroad Corporation said piece or part of said Troy & Greenfield Railroad when finished, together with the lands, buildings, etc., belonging, or that shall belong, to said corporation at North Adams, and

along said line to the Vermont line near Williamstown, said lease to continue until the completion of the Hoosac Tunnel, and no longer, and then the road and fixtures to be restored to said party of the first part, in good repair and condition.

The said railroad to be well and substantially built, and finished at the same time with the Southern Vermont Railroad, and to be then delivered to said party of the second part.

And the said Troy & Boston Railroad Company on their part agree and bind themselves to pay for the use of said railroad, as before herein described, the sum of eight thousand dollars per annum, during the time the same shall be held by the said corporation, and in that proportion for any lesser time. The same to be paid as follows: Four thousand dollars six months after the completion and delivery of the road and its acceptance, and the like sum semi-annually thereafter.

And on failure to pay the said sum or sums, the said party of the first part may resume said road and run the same, and in case the net earnings are insufficient to pay said rent, the said Troy & Boston Company shall be liable for the balance.

And it is further agreed and understood by and between the parties hereto, that they shall use their influence to bring about a proper and equitable consolidation of the Troy & Boston, Southern Vermont, Troy & Greenfield, Vermont & Massachusetts, and Fitchburg Railroads.

After the completion of said Hoosac Tunnel, if the Troy & Greenfield Railroad Company should run and operate the road to Pownal line, then it is agreed that the said Troy & Boston and Troy & Greenfield shall run in connection with Southern Vermont and Troy & Boston Companies solely, and divide the receipts for freight and passengers that shall pass from one railroad to the other pro rata, — that is, each road shall receive an equal amount for equal distance on said joint business between the village of North Adams and all points on the line of the Troy & Boston Railroad and Southern Vermont Railroad.

The Troy & Greenfield Company to furnish or provide such freight and passenger depot accommodations, turn-tables, wood-sheds, and water-tanks, and supply of water, as may be necessary for the convenient use of the road at Adams, and other points where necessary.

In testimony whereof, the said Troy & Boston and Troy & Greenfield Railroad Companies have executed these presents by their respec-

tive Presidents and Secretaries, and caused their respective corporate seals to be hereunto affixed the day and year first within written.

D. N. CARPENTER,
President Troy & Greenfield R. R. Co.
W. T. DAVIS,
Clerk Troy & Greenfield R. R. Co.
D. THOS. VAIL,
President Troy & Boston R. R. Co.
JARED REED,
Secretary Troy & Boston R. R. Co.

In presence of
C. B. Russell,
As witness to signatures of D. Thos. Vail and Jared Reed.

STATE LOANS.

The whole amount of State scrip advanced to the Troy & Greenfield Railroad Company, is as follows:—

Date of Advance.	Sterling Bonds.		
1858, October 6.	£22,500,	equal in dollars to	$110,475 00
1859, October 4.	11,200,	" "	54,992 00
1860, January 3.	11,300,	" "	55,483 00
" March 1.	6,800,	" "	33,388 00
" October 8.	18,000,	" "	88,380 00
" December 12.	26,500,	" "	130,115 00
1861, January 5.	7,500,	" "	36,825 00
" February 18.	5,800,	" "	28,478 00
" March 7.	4,900,	" "	24,059 00
" April 15.	in dollar bonds,		85,500 00
" May 7.	" "		
" June 26.	" "		37,500 00
" July 9.	" "		93,500 00
	Total amount advanced,		$778,695 00

The amounts which have been received on account of the sinking fund, and the interest thereon, to January 1,

1863, compounded annually at five per cent., are as follows: —

Date of Payment.	Amount.	Interest.
1858, December 31, . . .	$ 9,990 00	$2,155 59
1860, May 7, ...	4,972 80	688 65
" October 8, ...	8,036 40	927 10
1861, May 8, ...	23,111 11	1,944 23
" June 29, ...	4,852 46	372 12
Add interest, . .	6,087 69	
		$6,087 69
Value of sinking fund, Jan. 1,'63.	$57,050 46	

The interest on the loans, which has been left unpaid by the Company and advanced by the Commonwealth, and the interest thereon to January 1, 1863, compounded at five per cent., is as follows: —

Date.	Amount advanced.	Interest.
October 1, 1861, ...	$15,037 78	$949 27
April 1, 1862, ...	21,844 23	819 16
October 1, 1862, ...	23,539 72	294 25
Add interest, . . .	2,062 68	
Amount of accrued interest on State scrip from Oct. 1, 1862, to Jan. 1, 1863, ...	9,733 69	$2,062 68
	$72,218 10	

Amount of loan advanced, ...	$778,695 00
Add interest to January 1, 1863, ...	72,218 10
Total amount of advance and interest, ...	$850,913 10
Deduct value of sinking fund, January 1, 1863, . .	57,050 46
Net amount of advance, January 1, 1863, ...	$793,862 64
Add amount to be paid under act of 1862, ...	175,000 00
Total amount, ...	$968,862 64

We have left out of this account the $200,000 advanced on the Southern Vermont Railroad, regarding

that as an outside transaction, and not connected with either the completion or control of the Troy & Greenfield Railroad or Tunnel. We have also, for the same reason, taken from the interest actually paid the interest upon this advance.

In reducing the sterling bonds to their equivalent in dollars, we have estimated the £ sterling at $4.91, though we understand it was charged to the contractors at $4.44.4.

At the time of the delivery of sterling scrip, rejecting minor fractions, a £ sterling could be bought or sold in this market for $4.91 of United States gold coin. If the coin had been taken to England, $4.90 could there have been exchanged for the £ sterling. The equivalent then for a £ sterling was here $4.91, and in London $4.90.

We have estimated it at $4.91, because the election between dollar and sterling bonds was to be made here, and because it will cost the State the equivalent here, and not the equivalent in London, to pay the bonds, the difference being cost of transportation, &c.

In July, 1842, Congress enacted the following law: —

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in all payments by or to the Treasury, whether made here or in foreign countries, when it becomes necessary to compute the value of the pound sterling, it shall be deemed equal to four dollars and eighty-four cents, and the same rule shall be applied in appraising merchandise imported where the value is by the invoice in pounds sterling."
>
> "And be it further enacted, That all acts and parts of acts inconsistent with these provisions, be and the same are hereby repealed."

Under this law, invoices made out in sterling are estimated at $4.84 to the £, for the collection of duties

on imports. To this and many other purposes such a law is applicable and necessary, but it cannot alter the relative value of sterling and federal money.

We do not feel certain that the government rate of $4.84 is not the legal rate at which to estimate the £ in this case, but reason and equity seemed so strongly in favor of adopting the real equivalent that we have put it at $4.91.

The amount advanced in sterling was, ...	£114,500 00
Estimated at $4.91 to the £, it amounts to, ...	$562,195 00
It was charged to the contractors at, ...	508,888 00
The difference is, ...	$53,307 00
The interest which has been paid by the Commonwealth upon this overpayment is, ...	4,943 81
Making the total to January 1, 1863, . . .	$58,250 81

COST OF COMPLETION, TUNNEL EXCEPTED.

In making the necessary surveys, examinations, and estimates of cost for completing the road, the Commissioners desired to employ not only a man of suitable qualifications, but one who had not been previously connected with the work.

They selected James Laurie, Esq., of Hartford, Conn., a gentleman of acknowledged ability and integrity, whose estimates they regard as trustworthy and reliable.

He entered upon his work immediately after possession of the property had been acquired by the Commissioners. As his investigations required the careful examination of old, as well as the estimates in respect to new works, the time consumed has been considerable,

though not longer than was anticipated by the Commissioners.

In regard to the character of road required, the Commissioners felt bound to follow, as far as they were able to learn it, the intention of the Legislature. In looking for this, they found one of the main reasons for the advance of State credit to be the precedent in the case of the Western Railroad.

The security required by the Loan Act of 1859, for the issue of its credit, was to be similar in form to the security required of that Company.

If a road be constructed of a comparatively inferior character, the evident intention of the Legislature will not be complied with.

We do not think the following clause, from section 3 of the Loan Act of 1860, (chapter 202,) inconsistent with this view: —

> "No expenditures shall be required merely for the purpose of ornament, but the work shall be substantially performed, and the rails shall weigh not less than fifty-six pounds to the lineal yard. For any defective materials or work, a proportionate amount of scrip shall be withheld."

The intention of the law, as we understand it, does not conflict with our view of the character of the work required, when regarded simply in the aspect of a commercial undertaking.

The object sought to be accomplished by its construction is wholly inconsistent with the idea of an inferior road, which could only be operated at high cost, but requires a road which can be worked at the lowest rate, to give to it and the public the full value of any physical advantage it may possess.

The cost of the Tunnel is too great to be constructed for the convenience of a poor railroad.

For local accommodation, the Tunnel is not required; for through traffic, in connection with a second class railroad, it would be useless.

Mr. Laurie was, therefore, instructed to adopt as a standard for the quality and general character of construction the Western Railroad of Massachusetts.

His able Report will be found in the Appendix, and should command attention for its historical account and commercial discussion of this enterprise, as well as the more professional portion of it, relating to the cost and character of the work.

Character of the Line.

The line, as now located, is essentially a contractor's line; such a one as might fairly be anticipated where the contractor and engineer were the same person, intensified, if possible, by his controlling a majority of the stock. Every thing has apparently been sacrificed to save present outlay. That we do not advise the immediate abandonment of a considerable portion of it, is because of the large amount of work already done upon the most objectionable parts of the line, and the small amount of business to be done upon it until the Tunnel is completed, to which period, under existing circumstances, its improvement may wisely be deferred.

The general characteristics of the line between Greenfield and North Adams are as follows: —

Length of curves of $716\frac{2}{10}$ feet radius,	0.794	miles.
" " " " 764 to $818\frac{5}{10}$ "	0.387	"
" " " " 955 "	7.101	"
" " " " 1146 to 1432 $\frac{5}{10}$ "	4.425	"
" " " " 1910 to 2865 "	2.426	"
" " straight line,	21.885	"
Total length,	37.018	"

The total curvature is 4030 degrees.

The total rise and fall is $1046\frac{16}{100}$ feet.

The controlling grade, rising west, is $58\frac{63}{100}$ feet per mile, on a curve of 955 feet radius.

This is also the steepest grade rising west.

The controlling grade, rising east, is $39\frac{13}{100}$ feet per mile, on a curve of 955 feet radius.

Steepest grade, rising east, 40 feet per mile, on a curve of $1432\frac{1}{2}$ feet radius.

Distance from Greenfield to Shelburne Falls, . . .	13.13	miles.
" " Shelburne Falls to east end Tunnel, . .	17.02	"
Length of Tunnel, ...	4.84	"
Distance from west end of Tunnel to North Adams, .	2.03	"
	37.02	"
Distance from North Adams to the Vermont line, . .	6.15	"
Total length of road, ...	43.17	"

Slopes.

No doubt is entertained by the Commissioners that the slopes in all the earth cuttings, with possibly small exceptions, should be at least as flat as one and a half feet horizontal to one foot vertical.

It is impracticable to keep a road in good working order unless the ditches are kept clear and the road bed well drained; and this it is very difficult to do, if the slopes are not flat enough to keep the earth in place, and prevent its constantly filling them up.

After the road is opened for use, the road repairers cannot do the work of clearing them from these accumulations to any advantage, for the filling up occurs in wet weather, when the track requires more attention and labor, and when the very filling up of the ditches will call for a largely increased force to keep up the track, which will get out of order at once with the stoppage of the drainage.

Besides the increased cost of track repairs thus occasioned by the steep slopes, the frequent removal of the small quantity of earth as it washes down, filled with water, will cost much more than to do it all at once, while the work is constructing. Its after excavation, directly and indirectly, will cost several times the expense if incurred at the proper time.

Besides the washing being aggravated by the steep slopes, they cause frequent slides of large bodies of earth, covering up the track and stopping the traffic; and in the case of this road, where many of the cuttings are filled with boulders and loose rock, great danger would result from their rolling down upon the track, which in many places is so obscured by the sharp curvature as to give the enginemen but a very short view of the track ahead.

Since the work has been stopped, most of the slopes which were left at an inclination of one to one, have run down to about 1¼ to 1, and numerous slides of considerable magnitude have occurred, and this without the vibration of passing trains, which, after the line is opened, will greatly aggravate this tendency. Some small improvements have been made in the line at places where but little additional expense would be incurred, increasing the earthwork about 10,000 yards, and the culvert masonry about 175 yards, and the cost $2,525.

If the embankments along the Deerfield River were made the full width, the abrasion of the stream upon them, where unprotected, has washed away about 13,000 cubic yards. This, and the trifling change of line, may have added to the cost of completion about $5,000 or $6,000.

Temporary Structures.

Many of the temporary trestle works over ravines and watercourses will require strengthening before they can safely be used for the passage of trains.

The construction of some of these, in places where stone for the permanent work could not well be procured, except by the trains after the road is opened, was doubtless a wise measure of economy, but in others we think the permanent structures should have been put in at once.

Culverts and River Walling.

A large proportion of the culverts are faulty, either from bad construction or insufficient size, nearly one third of them having already been damaged or destroyed by the water. A portion of the bank or river walling has fallen down, and some of the remainder is too indifferently constructed to be permanent.

Green River Bridge.

This is much the most important structure of the kind upon the line. It is 706 feet long, 454 feet of it upon a curve of about 800 feet radius. It has been carefully examined by Mr. Laurie, to whose Report we would refer for a detailed account of it. It is, perhaps, enough for us to say, that we regard the location, requiring so high a bridge to be built upon so sharp a curve, exceedingly injudicious, and the bridge as bad in design, insufficient in materials, and faulty in workmanship.

This bridge might be propped up for temporary use while a suitable one was constructing upon a better location, or a new bridge, both in superstructure and masonry, could be built over the river and highway, which runs under the bridge near the river, altering the line a little so as to make this much of it straight, and filling in the curved portion with a solid bank; or stone arches could be put in for the highway and river, and then the whole filled up solid upon the present location.

Estimate of Cost.

The estimate of the cost of completing the road, following temporarily the present location, is based upon filling up about 260 feet of the curved part of Green River Bridge, and putting a suitable bridge in place of the remainder, filling in all the temporary structures except that at Hawks' Ravine, and putting new bridges in place of those built upon the plan of the present Green River Bridge.

ESTIMATE FROM GREENFIELD TO SHELBURNE FALLS.
DISTANCE $13\frac{13}{100}$ MILES.

For grading and filling in trestle work,		$72,317 00	
" masonry and foundations for same,		82,952 00	
" bridge superstructure,	$25,910 00		
less, materials on hand,	6,470 00		
		19,440 00	
" repairing culverts, alteration of roads, &c.,		2,300 00	
" crossings, cattle-guards, &c.,		1,500 00	
" land damages and fencing,		15,990 00	
" spikes and joint fixtures,		5,950 00	
" laying $8\frac{1}{2}$ miles track,		4,250 00	
" station buildings,		15,000 00	
" superintendence and contingencies,		15,000 00	
			$234,699 00

Total amount, ...	$234,699 00
If the line across Green River Valley be altered to make the bridge portion of it straight, the additional cost would be about, ...	$10,000 00
If arches be put in for the river and highway, and the rest filled in with a solid embankment, it would add to the estimated cost, ...	$35,000 00

Estimate from Shelburne Falls to east end of Tunnel. Distance $17\frac{2}{100}$ Miles.

For grading and filling in trestle work, .	$62,982 80	
" masonry, and foundations for same, .	59,409 00	
" bridge superstructure, ...	17,080 00	
" repairing culverts, altering roads, &c.,	9,000 00	
" crossings, cattle-guards, &c, ...	2,400 00	
" land damages and fencing, ...	33,030 00	
" laying $17\frac{2}{100}$ miles, ...	8,750 00	
" ties, ...	10,710 00	
" iron, spikes, and joint fixtures, . . .	36,000 00	
" station buildings, ...	8,000 00	
" superintendence and contingencies, .	15,000 00	
		$262,361 80
Total amount, ...		$262,361 80

Summary.

From Greenfield to Shelburne Falls, $13\frac{13}{100}$ miles,		$234,699 00	
" S. Falls to Tunnel, $17\frac{2}{100}$	"	262,361 80	
" Greenfield to " $30\frac{15}{100}$	"	$497,060 80	$497,060 80
Until the Tunnel is completed, the road would be operated principally for local business, and would require about $75,000 worth of rolling stock, which, if the road was not leased, would have to be added to the above estimate, ...			75,000 00

Making the total from Greenfield to the Tunnel, including rolling stock for local business, ...		$572,060 80
Some of the trestle work need not be filled in immediately. In this way there may be deferred from present outlay, without affecting the safety of the line, say, the sum of	$50,000 00	
Leaving, in case the road was leased, a present required expenditure of	$447,060 80	

By the time the Tunnel is completed the remaining portion of the line from the west end of the Tunnel to North Adams should be built.

The distance is about two miles, and the estimated cost, excluding buildings, but including land damages and station grounds, $67,500.

Even with the Tunnel completed, the road would not meet reasonable expectations as a through route, unless the lines between Greenfield and the Tunnel be considerably improved. It would probably be found judicious to expend in the improvements about $155,000, which should be done in time to use with the completed Tunnel.

There would then be required additional depot buildings, repair shops, tools, and fixtures, estimated to cost $75,000.

If this road should furnish its proportion of rolling stock for the through business, in addition to what might be necessary for its local traffic, the whole amount required for this expenditure is estimated at $275,000.

Deerfield Route.

Another line was surveyed from the Vermont & Massachusetts Railroad to Bardwell's Ferry. This line

5

commences about $1\frac{1}{3}$ miles east of the present terminus of the Troy & Greenfield Railroad, and keeping on the south side of the Deerfield River, crosses the Connecticut River Railroad south of the Cheapside Bridge over the Deerfield River, thence nearly parallel with that road to Deerfield Centre, and crossing the Deerfield at Martin's Falls, it joins the present location at Bardwell's Ferry.

The whole length of this line is 8.11 miles. It has 489 degrees less curvature and 150 feet less rise and fall than the present route, and reduces the maximum grade, ascending west, from 58.6 to 50.16 per mile; but this latter is not so important a gain as would appear, for the grade, ascending east, in the direction of the heaviest trade, is quite as strong relatively as the 58.6, rising west, in the present line.

Its adoption would involve the abandonment of $7\frac{7}{10}$ miles of the present line; as a through line, it would save nearly a mile in distance.

Its cost is estimated to be greater than that of finishing the line as at present located, by the sum of $97,975 80.

If stone arches and a solid embankment were adopted at the present Green River crossing, this difference would be reduced to $62,995 80.

The estimates in detail, and other information in relation to this line, will be found in Mr. Laurie's Report.

We do not think the advantage of this line over the present location sufficient to warrant a recommendation that the latter be abandoned, and so large an increased sum be expended upon the new route.

HOOSAC TUNNEL.

This great work, which has caused so much private, corporate, and legislative discussion and action, all fatally inadequate to its magnitude, the Commissioners have regarded as the chief object of their solicitude.

Its length is so great, and its character so unusual, that they have not felt at liberty to neglect any means of inquiry which promised to give them light in regard to it.

Improvements in the art of excavating works of this kind have, until within a very short time, made but little progress for many years.

Several machines have been invented to hasten and cheapen the boring of tunnels, but have failed to perform the required duty.

One of huge dimensions constructed for this work, enjoyed for a time much public confidence and expectation, but failed and was broken up after cutting some ten feet of tunnel.

Another has been tried and failed, but has not yet been removed from the work.

The confidence with which the largest of these machines was heralded, when first brought out, should lead us to be careful how we make calculations based upon the use of untried appliances, and perhaps should take out of us enough conceit to render us earnest inquirers and willing learners from all whose opinions are based on actual experience.

The railroad tunnels in this country, which from the nature of the ground cannot be provided with ventilating shafts, when necessary, at moderate expense,

are so short, that the question of ventilation has not necessarily been of much influence in determining their character.

In the Hoosac this is one of the great questions for consideration.

In Europe, where many comparatively long tunnels have been constructed, through which are passing large amounts of traffic, a great amount of experience, both as to their construction and use, has accumulated.

It is reasonable to suppose that, to a certain extent, the sum of this experience may have been gathered and acted upon by those now prosecuting much the largest work of this kind in the world, under the Alps, at Mont Cenis.

The Mont Cenis and Hoosac Tunnels are not, however, so nearly alike, in some of their characteristics, as to render it at all certain that those building the former would, if charged with the discretion, adopt a similar size and mode of construction for the latter.

We desired to learn the comparative cost and efficiency of hand labor and the drilling machines used at Mont Cenis, that being the first really successful application of machinery to the execution of such works.

Besides this, we have felt it our duty to have the large European tunnels examined, and the character of their means of ventilation studied, by a competent person, who had no motive to degrade their good qualities, and no interest to shield their defects from rigid scrutiny.

Charles S. Storrow, Esq., was selected by the Commissioners for this important duty. His superior qualifications for this mission need no comment from us. His interesting and instructive Report will be found in the Appendix, and we commend it to the most careful

and attentive perusal, as containing the latest chapter in the world's progress in this direction.

We have also had the locality examined by BENJ. H. LATROBE, Esq., a civil engineer of eminent ability, who has probably executed more tunnelling than any other man in America.

His authority we consider quite as good, upon a work of this kind, as that of any other engineer in the country.

His Report follows that of Mr. STORROW, in the Appendix, and will well repay a careful reading.

Mr. LAURIE, who made the general surveys and estimates, also gave to the Tunnel his most careful attention. His valuable discussion of the subject will be found in his general Report in the Appendix.

Description of the Mountain.

The Hoosac Mountain, which is pierced by the Tunnel, has two summits, with a wide valley between them. The eastern summit is 6,100 feet from the east portal of the Tunnel, and 1,415 feet above the grade of the road; and the western summit 6,700 feet from the western portal, and 1,704 feet above grade.

The summits are $2\frac{41}{100}$ miles distant from each other; and the valley between, at its greatest depression, is 801 feet above grade.

A part of the line over the Tunnel is covered with forest, and in some places the depth of earth above the rock is quite considerable.

In a portion of the valley between the summits the land is swampy, drained by two small streams of water, which unite near where they cross the line of the Tunnel.

The rock, so far as the Tunnel has been driven, (2,394 feet from the east end,) is a mica and talcose slate, with occasional veins and irregular masses of quartz, and is quite uniform. Specimens have been taken from the frequent outcroppings across the mountain, which indicate a similar material, with an occasional tendency toward the character of gneiss, except for the distance of about half a mile from the west portal, where a secondary overlays the primitive formation of the mountain. This, so far as penetrated, is composed of hard silicious rock and some limestone, in a very disturbed condition, covered by a large body of clay, sand, gravel, and boulders, full of water, with a considerable stream crossing the line about 800 feet east of the western portal. The construction through this cannot be otherwise than expensive.

Commencing at the east side of the mountain, the stratification dips eastward, at an angle of 60 to 80 degrees from horizontal, changing, two miles from the east end, to a dip of but 22 to 30 degrees, which continues for the next half to three quarters of a mile. Beyond this the dip changes to the westward, and lies at an angle of from 20 to 32 degrees,—the anticlinal axis occurring about $2\frac{79}{100}$ miles from the eastern portal.

A table, showing in detail the results of this exploration, will be found in Mr. Laurie's Report.

A profile of the mountain, showing the dip of the strata, will also be found in his Report.

Assuming that the outcropping rock is a fair indication of its character on the line of stratification down to the grade of the Tunnel, there remains unexplored at the tunnel level a distance of about 3,900 feet, lying

between the strata dipping east and the strata dipping as indicated at the surface.

The following extracts from President Hitchcock's testimony before a committee of the Legislature, in 1854, give his opinion, as a geologist, upon the character of the rock in this mountain.

"There is scarce any thing in the mountain but this mica slate, occasionally mixed up, however, with a little quartz, of an imperfect kind, which does not differ materially from the mica slate in hardness.

The whole mountain is made up in the same way. There is no granite or trap intruded in the form of veins or dikes. It is of extremely simple formation, as it is throughout the whole of the Green Mountains, and down through the Hoosac range.

There are, occasionally, nodules of quartz in this rock, as you go down to the westward of this mountain, in the town of Adams. I do not know exactly where the tunnel is to terminate, but there is a bed of this quartz which is very hard, and it is possible the tunnel may have to pass through it, some little distance, on the western slope.

I cannot say, positively, whether or not it does pass through it, not having been on the precise route of the tunnel in that locality.

Iron ore is very frequently found in connection with quartz rock and limestone. You will find bits of iron ore on the surface, but cannot tell where the beds will occur till you dig down.

As I have said, I do not know whether or not these foreign rocks occur where the tunnel is to pass, only that quartz and limestone exist in Adams. I have noticed this rock (mica slate) all the way over the mountain, and it has this same appearance. It is the same rock all the way till you get near the foot, on the west side. I have no doubt at all that the whole mountain is composed throughout of this mica slate as well as on the surface, and probably it is the same rock thousands of feet lower than the Connecticut River.

I do not believe there will be any cavities found in the mountain; there may be slight ones; but, if so, they will be caverns, and not filled with earth, like the soil or gravel of the surface.

I do not think there will be any masonry or arching required. For instance, if the boring machines should be found to operate well, and the tunnel should be bored through the mountain, I do not believe that it would require any more masonry for its support than would be

necessary for a good, sound stick of timber, with an auger hole bored through it. A little masonry may, of course, be required at the ends; but I have so much confidence in this opinion that I should not be afraid to engage to put in all the masonry that will be necessary, after you get beyond the surface, for a very few thousand dollars.

If there is any confidence to be placed in the principles of geology, then we may rely upon the rocks' proving to be the same throughout the mountain, without cavities.

It would be a thing unheard of in geology otherwise.

I know of no place where you will find soil after you get into the solid rock, unless it is where a valley comes down from above.

Undoubtedly the rock will be much easier to work after you get down through the edge.

The tunnel will support itself just as well a little inclined as if the rock stood perpendicularly.

There is no question but that the rock is easy for drilling, but I am told that powder, in blasting, does not throw out so large a mass as in the case of some other rocks, which are harder to drill and more easily cracked by powder.

It will be more easy to pass through the layers than if they were horizontal.

Water will, undoubtedly, be found near the surface, and elsewhere, to some extent; but I have an impression, or rather an opinion, that this tunnel will be found to go below where the water percolates, unless the layers are found to be more broken than I suppose they are."

The shaft which has been driven down to the line of the Tunnel, at a point 3,008 feet easterly from the western portal, shows rock of the same character as that at the east end.

This fact, and the surface examinations across the mountain, with President Hitchcock's opinions, as quoted, are strong evidence of the general uniformity of the rock through the mountain.

The cost of removing large quantities of water, if it found its way into that portion of the work executed through shafts, would be very large.

The worst, however, that could happen from this

cause would be an abandonment of the shaft workings and a completion of the Tunnel from the ends.

There is, perhaps, more chance of the rock being less close and perfect near the anticlinal axis, where a possible disturbance may have occurred, than at any other place. This point is 4,600 feet eastward, and 375 feet above the brook which is in the lowest part of the valley, with the strata dipping from the higher ground westward under the valley below.

The water from the swampy ground of the valley will, therefore, not be likely to reach any possible openings which may exist where the dip of the strata changes.

The inclination of the strata is much more favorable for keeping out the water than if its direction was vertical.

While, therefore, there can be no certainty in respect to trouble from water, we regard the general indications as quite favorable.

The whole length of the Tunnel, as generally understood, and as reported to the Legislature, is 24,100 feet, or $4\frac{56}{100}$ miles; as found by survey, it is 25,574 feet, or $4\frac{84}{100}$ miles; as proposed by the Commissioners, it is 24,586 feet, or $4\frac{66}{100}$ miles.

The mountain, at the east end, has been penetrated a total distance of 2,394 feet, to the end of the heading, which is about 280 feet beyond the bottoming.

The size of tunnels, as usually given, is that above the grade line, or above the top of the rails, the excavation being enough deeper to provide for the track, ballast, and drainage.

If the minimum size intended to be given to this Tunnel was 14 feet wide and 18 feet high above the rails, the total height of excavation would have to be

20 feet. If it was intended to have the whole excavation but 18 feet high, then the height above the rails would be but 16 feet, and the area above the surface of the ballast 14 feet by 16 feet 4 inches.

The excavation, as made, does not conform to any particular line or grade; nor is any part of it, except the end sections, cut so large as the smallest size given above as the minimum required.

If a track was laid through it crooked to conform to its line, and undulating to conform to its grade, it would be too small to pass an ordinary train without hitting. The height in some parts of it would be only $11\frac{35}{100}$ feet above the ballast, or 11 feet above the top of the rails. It would cost a large sum to recut it to a straight line and regular grade, and enlarge it to the minimum size, before given, of 14 feet wide and 16 feet high above the rails.

Cross sections of it, as cut, are shown in PLATE A, at end of Commissioners' Report.

SIZE, DRAINAGE AND VENTILATION OF TUNNEL.

Both ends of the Tunnel are upon nearly the same level.

The necessities of drainage, therefore, require a central summit. The grade, upon which a portion of the opening has been driven, is too irregular to indicate what rate of rise was intended.

The centre will be elevated above the ends from 50 to 60 feet, depending on the amount which the grade may be reduced at the summit.

Where many shafts are constructed, they are often

found to, in some degree, neutralize each other, and rather harm than help the ventilation.

From a large number of Tunnels described in the Appendix, we give the principal characteristics of a few, selected as most pertinent to our general inquiries.

Box Tunnel.

The "Box Tunnel," on the Great Western Railway, in England, (see page 6, in Mr. Storrow's Report,) is nearly two miles long, thirty feet wide at its widest part, and twenty-four and a half feet high above the rails, and was originally constructed with seven shafts.

Two of them have been closed, and some of the people connected with the work would be glad to see the rest of them closed.

The grade through this is on one incline, at the rate of $52\frac{8}{10}$ feet per mile. When the trains pass up the grade, the smoke becomes quite dense. When they pass down, they use but little steam, and a quick train on the down grade is the efficient agent for clearing the Tunnel.

The good effect of this is supposed to be reduced by the shafts.

Its very large dimensions must greatly reduce the bad effect of the up trains upon its atmosphere.

Sapperton Tunnel.

The "Sapperton Tunnel," upon the same railway, is 28 feet wide, and 20 feet high, and one mile in length.

All its shafts but one have been closed, and that one all but an opening four feet by five, which is probably useless for ventilation. The grade is all one way, at the rate of $75\frac{43}{100}$ feet per mile.

The steep grade makes heavy work for the engines going up the incline, and a single freight train fills it with smoke, which is for hours quite offensive. If two freight trains follow each other up the grade, it is very difficult for the men to work in the tunnel; and if four follow each other, it is impossible.

A passenger train running down the incline at great speed is the effectual means of ventilation.

Woodhead Tunnel.

The "Woodhead Tunnel," on the Manchester, Sheffield, and Lincolnshire Railway, is a double tunnel, with a longitudinal pier, 21 feet wide between the two chambers, each of which is 14 feet 4 inches wide, and 18 feet 3 inches high above the rails. The length is almost three miles, and it has five shafts now open. There are 21 arched openings through the piers, connecting the two chambers. The grade is all in one direction, at the rate of $26\frac{4}{10}$ feet per mile. This tunnel, like the "Box," has better ventilation on some days than on others. The current in the shafts is sometimes upward and sometimes downward. One of the chambers was worked several years as a single tunnel before the other was built. It was then often quite smoky, and now, when, to facilitate repairs, the traffic is all turned through one chamber, it is sometimes oppressively so.

Lindal Tunnel.

The "Lindal Tunnel," upon the Furness Railway, is about one third of a mile long, and upon a grade of $52\frac{8}{10}$ feet per mile. It was originally built but 12 feet wide and 14 feet 6 inches high. An increased traffic

required its enlargement for a double track. The contractor preferred to build a second tunnel to enlarging the old one at the same price, but the excessively bad ventilation of the old one determined its enlargement.

During the process, the workmen sometimes found it impossible to remain at their work, the engines so completely filling the tunnel with smoke and sulphurous vapor. The best means of clearing it was to run a light engine rapidly through it. Since the enlargement no complaint is made of its ventilation. The difficulty which existed before, in spite of the moderate length of the tunnel, and its favorable grade for ventilation, was therefore wholly due to its small size.

Almondsbury Tunnel.

The "Almondsbury Tunnel," now under construction on the Bristol and South Wales Junction lines, is for a single track. It is 17 feet wide at the rails, 18 feet 6 inches greatest width, and 19 feet high above the rails. There are five shafts, but these are intended to be closed when the work is put in use.

The length is three quarters of a mile, and the grade 58.66 feet per mile.

The fact that this tunnel is now under construction, and its proportions determined from the latest experience, should have much weight in its consideration. Its grade is very favorable for ventilation. Its length is quite moderate. It is built for a single track, and still its sectional area above the rails is 34 per cent. larger than the present largest area of the Hoosac.

The remarks of Mr. Storrow, in his Report in relation to this, and his conversations with its builders and engineers in relation to the Hoosac, will be found very interesting and instructive.

Hauenstein Tunnel.

The "Hauenstein Tunnel," in Switzerland, is over a mile and a half long, and in section 26 feet wide and 20 feet high above the rails. The grade rises through the tunnel at the rate of 132 feet per mile.

It has no shafts for ventilation. There are canvas curtains at the ends, which are closed in winter to keep out the cold, and at other times to check the draught, which is at times so strong as to be inconvenient to the trains.

Ordinarily the ventilation is very good, but occasionally bad enough to somewhat annoy the workmen. The north end of this tunnel is more than 200 feet higher than the south end. It may almost be called an inclined chimney, and if the high end was on the south or warm side of the mountain, it would probably never be troubled with smoke. As it is, the colder air at the north end may, in some states of the atmosphere, become of the same density as the lower air at the south end, and the ordinary effect of the great difference in elevation be neutralized.

Mont Cenis Tunnel.

The "Mont Cenis Tunnel," now building under the Alps, is more than seven and a half miles in length, and in section 26 feet 3 inches wide at its widest point, and 20 feet 8 inches high above the rails.

The grade rises from the French side at the rate of 117.22 feet per mile to the centre, and then falls at the rate of 2.64 feet per mile to the Italian side of the mountain. This last grade is made as light as it can be and serve the drainage, as all that it

falls impairs the draught or ventilation through the tunnel.

The rails at the highest point are, however, only 10.4 feet above those at the Italian end, which leaves the top of the arch at that end nearly eleven feet above the track at the summit.

The entrance to the tunnel on the Italian side is 435 feet higher than that on the French. This great elevation, added to the warmer atmosphere on the south of the mountain, is probably relied upon to produce the necessary current for ventilation.

We suppose the most careful consideration has been given by most competent men to the proportions of this gigantic work, and that to all prior experience due weight has been given in arriving at a result.

Though their prospect of obtaining a strong draught through the tunnel is good, yet they have deemed it necessary to give it a section more than twice as large as that heretofore fixed for the Hoosac.

It is not unusual for tunnels in Europe to have a summit within them, where the track is a few feet lower than the roof at the highest end, but Mr. Storrow heard of no case like the Hoosac.

Kingwood Tunnel.

The "Kingwood Tunnel," on the Baltimore & Ohio Railway, is about three fourths of a mile long, and in section 22 feet wide and 21 feet high above the rails, and is on a grade of $52\frac{8}{10}$ feet per mile.

When several freight trains follow each other up the grade, inconvenience is at times felt from the smoke, though the men are required to enter the tunnel with their fires as clear as possible, and disturb them as little

as practicable during the passage. At ten miles an hour, each locomotive would be in the tunnel only four and a half minutes; for so short a time fresh coaling would rarely be necessary, and comparatively but little smoke would be emitted. If the Kingwood was as long as the Hoosac, instead of only one sixth as long, no such expedient could be resorted to, and its ventilation might then be quite unsatisfactory.

Hoosac Tunnel.

Besides the question of ventilation, there are many other objections to a section so small as that on which the Hoosac has been commenced, only 14 feet wide and 18 feet high.

If considerable water should be met with, the room for drainage at the sides, which is the usual method in this country, will be quite limited, and the road bed between the ditches be so narrow as to require much more attention and labor to keep the track in order, while the limited room will make the work inconvenient and more expensive. The same amount of work will cost more, and there will be more work required, and, what is still more important, the track will not be likely to be kept in the best possible order; when for safety and to help the traction, which is always comparatively bad where the rails are wet, as in tunnels, the track should be kept in the most perfect condition.

If a train was delayed in the Tunnel, which must occasionally happen, the room to get about it and do any repairs is very small, — only about two feet each side of a passenger car, — and the smoke of the engine would soon fill the little area about the train, and might prove most disastrous to the men and passengers, and if thrown from the track, the results would be fearful.

If a freight train should get off the line in so small a chamber, it might get wedged in and fill it so full as to cut off the draught, when the smoke and gas would speedily drive out all who were able to get away, to say nothing of the disaster to the trainmen; besides, the traffic of the line would be seriously interrupted.

Great care has been taken to obtain the opinions of the best authorities in England and on the Continent, among those of the most enlarged experience, both as to the construction and use of long tunnels; and while they have been found to differ in some respects in regard to minor details, the opinion is universal and without a single exception among them, that the present section of the Hoosac is altogether too small, and that the area of the original design is the least that should be counted on as promising any success to the enterprise.

These authorities are all as perfectly agreed that a shaft in the centre is indispensable.

On these points Mr. Storrow obtained the views of many more persons qualified to judge than he has named in his report.

Mr. Latrobe thinks the area of the section should not be less than 45 square yards. The minimum section authorized for the Hoosac is 25½ yards, and the original design 45 yards. He would prefer two shafts, as insuring better ventilation than one.

Mr. Laurie thinks the present section entirely too small, and that it should be built large enough for two tracks; and while he is not so clear that the want of a shaft would be fatal, he would advise it, as removing any doubt about the ventilation.

The simple statement that the ends are on nearly the same level, that the central summit will be from 40 to 60 feet higher than the ends, that no train can pass

through it without emitting a large amount of smoke and gas, which will be lighter than the atmosphere at either end, we think is enough, without further discussion, to show that the risk of noxious accumulations in the higher and central parts of the Tunnel is too great to allow the shaft to be omitted.

With a shaft, it is thought that the draught would be quite strong, and the ventilation satisfactory. If, however, from the state of the atmosphere, or other causes, it was occasionally otherwise, a fire in the shaft would create an artificial draught, as in the case of deep mines, and correct the evil at once.

Most of the long European tunnels which have been examined, are either wholly, or in large proportion, lined with smooth masonry.

Whatever increased facility this gives to the draught and ventilation — and it would seem quite considerable — will be lost to the Hoosac, the surface of which is nearly all expected to be rough, as it is left by the blasting in excavation.

It has been suggested that a small tunnel, not very unlike the minimum authorized by law, say 14 feet wide and 18 feet high, be first built, and then enlarged, if found too small. If it was found decidedly too small, as we think it would be, its use would have to be dispensed with through the years of its enlargement. The interest upon its cost, through this period of its disuse, would largely swell the expense of the work. If it was found large enough to be used for a small traffic, with very infrequent trains, or in the best states of the atmosphere, it is apparent that it could not be used during its enlargement, without involving an additional cost, wholly disproportionate to the value of such partial use as was practicable.

If one train could not follow another without an hour of interval, neither could the men work in that interval, and they would lose the additional time of transit in and out, besides working indifferently in the bad atmosphere, which would prevail nearly all the time. It is doubtless possible to enlarge and use it at the same time, in the view that almost any thing in engineering is possible, with money and time enough; but we regard the plan as clearly out of the question in this case.

Beyond this, we think it would not be creditable or desirable for the State of Massachusetts to construct the Hoosac Tunnel more than once.

Regarding the shaft as likely to be the main dependence for ventilation, steep grades, rising each way towards it, would seem to facilitate the passage of the lighter gases up the grade and to the outlet; but the steeper the grade, the greater the amount of smoke and gas that will be emitted from the locomotives, and this probably increases more rapidly than the increased facility for ventilation caused by the steeper grade. The grades are, therefore, arranged as follows: Rising from North Adams towards the Tunnel, with a grade not exceeding the eastward maximum of 40 feet to the mile, but enough to bring the grade at the mouth of the Tunnel twenty-five feet above the present grade; thence rising, for half a mile through the wet cutting, at the rate of $26\frac{4}{10}$ feet per mile; the next half mile at the rate of 20 feet per mile; thence for a mile, at the rate of 15 feet per mile; thence over the summit, with a grade as flat as the smaller drainage there required will permit; thence on a grade which will come out at the east end of the Tunnel as now cut, which will require about 25 feet per mile.

The grade is laid as nearly level as possible at the

summit, to facilitate drainage during the construction of that part executed from the central shaft.

The grade thence westward is increased with the distance from the centre, to pass the accumulating quantity of water.

The grade thence eastward is uniform, because the necessary descent gives a sufficient rate per mile to drain any part of it.

We would recommend the section of the Tunnel to be nearly as originally designed,—say 22 feet wide at the grade line, 24 feet wide at the widest point, 21 feet high above the track; the roof to be circular. See PLATE B. This is large enough for two tracks, should they ever be required, and as small, in view of the difficulties of ventilation, as we think it prudent to construct it.

We prefer the circular roof, because it will be stronger, and because the draught through it will be something better than if the outline be made of more angular form.

European tunnels are generally drained by means of a culvert constructed under the road bed, in the centre; American tunnels, by open drains at the sides. Experience in working the rock should be left to determine which plan would be the most economical in this case.

As the shaft will most likely become the main reliance for ventilation, it should be of liberal dimensions; and we would recommend it to be of an area equal to a circle of 20 feet diameter, of such form, (probably a little elliptical,) as shall be thought most judicious. PLATE C shows a profile of the mountain, grade of the Tunnel, and location of the shaft.

COST OF HOOSAC TUNNEL.

The estimates of cost made by Mr. Storrow, Mr. Latrobe, and Mr. Laurie, are all based upon hand labor.

Mr. Storrow found that the machine drills, so successfully used at the Mont Cenis Tunnel, however much they may have hastened the work, did not reduce its cost.

We think the opinion is quite general among contractors that, as heretofore used, they have not been money-saving appliances. This view, however, may result from the considerable cost of preparing to use them for works of ordinary magnitude, and the fact that rapid progress is rarely regarded by contractors as worth paying for.

We are not prepared to admit that a considerable saving may not be made by their judicious application at the Hoosac. The difference in cost between machine and hand labor is greater in this than in any other country.

At Mont Cenis they are working against common labor, which costs 60 cents per day. At the Hoosac they would work against labor costing, in ordinary times, a dollar per day. This is a very large difference in favor of the machine work for this country.

Only a portion of the labor is performed by them, and on this portion only is the saving to be made.

It will require, in part, skilled labor to use the machines here, as well as at Mont Cenis. This has raised the average cost of their labor to about 70 cents per day, and would probably add 15 or 20 per cent. to it here; but this does not alter the fact that, whatever value there is in the machine work, is there compared with common labor at 60 cents, while here the labor costs a dollar.

If our better educated labor manage the machines to better advantage, which is quite likely, something may be gained in that way.

The cost of getting up the necessary machinery, beyond what is required to supply fresh air to the workmen, will be quite considerable, and its earliest working will be somewhat experimental. We are, therefore, inclined to base our estimate of cost upon hand labor, and leave the probable savings from the use of machinery, to affect any unforeseen contingencies which may arise in a work of such magnitude.

Our estimate will be based upon President Hitchcock's opinion, the highest attainable authority, that the quantity of water to be met with, except in the secondary formation at the west end, will not be so large as to be seriously troublesome.

It is found that long tunnels, all other things being equal, cost much more than short ones.

Whatever increase is due to the difference between short and ordinarily long ones, will be much greater in one of such exceptional length as the Hoosac.

On the other hand, the cost of a tunnel through rock can be much more reliably estimated than through any other material.

For obvious reasons, the cost of shafts increases very rapidly with the increase of their depth. This is well illustrated in the cost of the 24 shafts of the Nerthe Tunnel, shown in Mr. Storrow's Report, in the Appendix.

The average cost of the first 197 feet in depth was	$11 03 per foot.
From 197 feet to 328 feet in depth	16 00 " "
" 328 " " 459 " " "	19 41 " "
" 459 " " 610 " " "	23 38 " "
While the average cost of five of them which were but 67 feet deep, was only	8 88 " "

These shafts were very small, only ten feet in diameter.

Raising the grade 25 feet at the west end, might make it practicable to extend the open cutting about 988 feet, and shorten the Tunnel thus much.

This would bring the deepest open cutting to about 85 feet, the lower portion of which would be rock, and the upper part earth.

There would then remain to be excavated and arched through that very bad material, perhaps 1,350 feet, before coming to the primitive formation, where the rock would be firm enough to stand without lining.

This distance is, of course, to a great extent, conjectural, and can be at best but an approximation. It is, however, but 670 feet further to the west shaft, where the rock corresponds with the supposed general character of the mountain, and indications are that it extends to a point quite as far westward as we have estimated for the east end of the bad material.

Our estimate of cost is as follows: —

About 988 feet of open cutting at west end, to a maximum depth of about 85 feet, .	$60,000	
Excavating and arching 1,350 feet through the secondary formation, at $200 per foot,	270,000	
Excavating Tunnel under the mountain 20,936 linear feet, containing 16 cubic yards per foot, in all 334,976 cubic yards, at $5 per yard, ...	1,674,880	
Enlarging 2,300 linear feet of Tunnel at east end, at $30 per foot, ...	69,000	
Sinking central shaft, 20 feet in diameter, including machinery, 1,027 feet in depth, containing 11,944 cubic yards, at $22 per yard, ...	262,768	
Amount carried forward, . .		$2,336,648

Amount brought forward, .	$2,336,648	
Five miles of railroad superstructure of extra quality, including taking out the old and putting in new ballasting, at $12,000 per mile, ...	60,000	
Add for contingencies, engineering, &c., at 12½ per cent, ...	299,581	
Total cost, exclusive of interest, ...		$2,696,229
Interest at 5 per cent., compounded during eight years of construction, ...		522,094
Total, including interest during construction, . . .		$3,218,323

This estimate, as well as that for completing the road, is based upon ordinary labor, costing one dollar per day.

It was intended to place a pretty high estimate upon the first and second items, as it might be judicious to force the work upon these two at some extra cost, to save the expense of elevating and pumping at the west shaft, and to earlier obtain the increased speed and other advantages of working at an end face, instead of an interior one, in driving the main body of the Tunnel under the mountain from the west.

Exposed, as such works are, to the development of hidden difficulties, we present this estimate with a due sense of the uncertainty which pervades it. We can only say that, unless President Hitchcock's views of the interior character of the mountain, are widely astray, we think it is sufficient.

It will be noted that Mr. Storrow estimates the cost, exclusive of interest, at	$3,000,000	
Interest compounded for 10 years, the time he estimates for building, . . .	773,368	
Total, including interest		$3,773,368
Mr. Latrobe, adding $60,000 for superstructure, which he omitted, at		$2,837,485
Mr. Laurie, with a central shaft and hand labor, at .		$3,430,780
" " " " " " drilling machines,		$3,050,180

TOTAL COST OF ROAD AND TUNNEL.

The cost of the Road and Tunnel, including the equipment, together with the interest, at five per cent., compounded until the Tunnel is completed, is estimated as follows:—

Advances already made, with interest to January 1, 1863, including the $175,000, (special appropriation, 1862,)	$968,862	
Interest for eight years, ...	462,585	
		$1,431,447
Expenditures immediately required to open the road east of the Tunnel, ...		447,060
(The interest on this is supposed to be paid out of rents and earnings to be received while the Tunnel is constructing.)		
Cost of permanent works, to go in as the temporary structures fail, ...		50,000
Cost of straightening and improving the line, to be done the last before the Tunnel is completed, ...		155,000
Cost of constructing the 2 miles between North Adams and the Tunnel, ...		67,500
Additional depot buildings, shops, &c., required when the whole line is completed, ...		75,000
Cost of rolling stock for completed line, ...		275,000
Estimate for Tunnel, ...	$2,696,229	
Interest during construction, ...	522,094	
		3,218,323
Total estimated cost and interest, ...		$5,719,330

TIME REQUIRED TO BUILD THE TUNNEL.

The difference between the rate of progress for a month, or a year, and the average rate upon the whole of so extensive a work as this, may be very great.

It is not uncommon for the time occupied in constructing a long tunnel to be from two to four times as much as that indicated by the best progress made upon the work. These wide variations in the rate of progress occur in works of very difficult character, and mostly where the material is variable and uncertain; the influx of large quantities of water creating more delays than all other causes. The time required to construct the work through the disturbed formation at the west end, is apparently more uncertain than that of any other part. Fortunately this is but a small portion of the whole work. Next to this, the central shaft, from its great depth, may develop unforseen difficulties and causes of delay.

The character of the work in the vicinity of the anticlinal axis, down at the level of the Tunnel, is less certainly determined than that of the rest of the mountain, and unexpected difficulties may occur in this part of the line. The main body of the work, however, shows good promise of regularity in material and rate of progress. The best result upon the east end of this Tunnel, for ten months, was $54\frac{1}{2}$ feet per month for the heading, and 46 feet per month for the bottoming, the heading having been made at the top of the Tunnel.

Mr. Storrow estimates the progress of hand labor at 60 feet per month, per face, on the Tunnel, and 22 feet per month on the central shaft.

Mr. Latrobe, at 50 feet per month on the end faces and $33\frac{1}{3}$ feet on the interior faces of the Tunnel, and $17\frac{1}{3}$ feet in the shaft.

Mr. Laurie, at 55 feet per month on the end faces, 40 feet on the interior faces, and 21 feet on the shaft.

The Commissioners will estimate, for hand labor, a progress on the ends of 55 feet per month, on the interior faces 35 feet per month, and on the shaft 20 feet per month. It may, in practice, be found expedient not to work from the west shaft any further to the westward than the primitive formation extends. At all events, it will not be wise to work so far in that direction as to let into this working much of the water from the wet material overlaying the rock in this locality. The delay, if any, from this cause, will not be very great. It will, for the time, occasion a loss of progress equal to the difference between working at an end and an interior face, the interior face continuing to be worked until the end is opened.

The lengths of different parts of the work are as follows: —

	Feet.
Length of proposed open cutting at west end, ...	988
From thence to west shaft, ...	2,020
West shaft to end of cutting at east end, ...	20,266
Average length driven from east end, ...	2,300
Total length between "Old Portals,"	25,574
Deduct proposed open cutting, ...	988
Total length as proposed, ...	24,586

We suppose the open cutting at the west end may require twelve months to excavate. At the same time, the working from the west shaft westward, at 35 feet per month, will have been driven 420 feet, leaving 1,600 feet to be driven from one end, and one interior face, making together 90 feet per month. This would take eighteen months, which gives thirty months to open it through west of the shaft. The working between this shaft and the east end will have made progress as follows: —

	Feet.
From the shaft working, 30×35 feet $=$	1,050
" " east end " 30×55 " $=$	1,650
This, ...	2,700
deducted from length between western shaft and east end working, say, ...	20,266
Leaves to be driven, ...	17,566
The depth of the central shaft to the grade line of the track is 1,027 feet; at the rate of 20 feet per month, it will require 52 months to sink this, leaving 22 months to work from the two end faces before work can be commenced through the central shaft.	
The progress made in this time, at 55 feet per month, would be, 22 months, at 110 feet, $=$	2,420
Leaving yet to be driven, ...	15,146

This would be driven from two end faces and two interior faces, or at the rate of 180 feet per month, and would require about eighty-four months.

This requires eleven years and four months to complete the whole work by hand labor.

If at the end of twelve months machine drills were introduced at the east end and at the eastward working from the west shaft, a progress of 110 feet from the east end and 70 feet from the shaft working might reasonably be counted on.

	Feet.
Total length between west shaft and east working, . .	20,266
12 months at $35 + 55 = 90$ feet per month, ...	1,080
Leaving to be done when machines begin, say, ...	19,186
Until the west end is cut through to the shaft, the rate would be 180 feet per month, which, for 18 months, is	3,240
	15,946
The work would then be from the end faces till the central shaft was done, and the rate 220 feet per month for 22 months, say, ...	4,840
Leaving to be worked from two end and two interior faces,	11,106

If the two interior faces were worked by hand labor, and the end faces by the machines, the total progress would be 290 feet per month; which would require about thirty-eight and one third months to complete it, and make the total time about seven and a half years, as illustrated by PLATE C.

It is quite possible that the machine drills may be used in sinking the central shaft, and in subsequently driving the headings from it. The chances of increased speed from this source are, perhaps, sufficient to counterbalance any delay likely to occur in other parts of the work, and make from seven and a half to eight years a reasonable estimate of the time required to complete the work from the time it is vigorously undertaken.

METHOD OF COMPLETING.

It has occasionally happened in this country that capitalists have been found to aid in the construction of a railroad by the purchase of the bond obligations of a company having a doubtful stock list.

Stock taken by contractors seldom strengthens, but very generally weakens, a corporation. It is rarely paid for, either in money or work, but simply reduces the value of what other people are asked to pay full rates for.

If those proposing to lend their credit or their money to such a company require an additional million of stock to be subscribed, the contractors and their friends can take it if a million be added to the price of their work. By this operation, the bonds would be strengthened as much as those taken some years ago by an iron manufacturer, who sold his rails for half bonds and half

cash; but double the necessary quantity was required of him to enable the company or contractor to sell half, and get the necessary cash to keep faith with him.

It is not reasonable to expect from the managers of an irresponsible company, who have no interested constituency to protect, that care and unremitting vigilance in the expenditure of other people's money which is necessary to the economical construction of a railroad. There is, probably, no shorter road to bankruptcy than through such experiments.

We do not suppose that either of the companies interested in the completion of this line, even if in a position to undertake it, would consider it just to their proprietors that they should embark in a work so foreign to their expectations. It is doubtful if they could legally do so.

The only course which seems to us as free from embarrassment, and likely to lead to a successful result, is for the State to undertake the work on its own account, controlling its own agents, and holding them responsible for the integrity of their management.

We are aware that works constructed by States are usually expensive; that changes in their management often occur with changes in the civil administration; that men are frequently placed over them because of their political influence, rather than their peculiar fitness: and great waste is the inevitable result.

But we venture the suggestion that, even with this excessively injudicious management, the losses have been but small compared with those resulting from a loan of credit to companies of doubtful responsibility.

Excepting the construction of the Tunnel, it would doubtless be found advantageous to complete most of the work by contract. The Tunnel, we think, should

be constructed directly by the State. To build it rapidly, and in the end most economically, would require a pretty liberal early expenditure for machinery and other preparation.

To carry it on as rapidly as a due regard to the saving of interest upon its cost would require, is more likely to be done by the State than by a contractor.

It would not be prudent for any man, having sufficient capital to guarantee its construction, to embark in it, except at a price so high as to cover all risks, and much higher than it may fairly be expected to cost.

It would not be wise, or according to any precedent, for the State to expect to get the work done at the contract price if it should turn out to cost more. It would certainly get no abatement if the price was found to be exorbitant.

We are clearly of the opinion that it should not be constructed by contract, excepting in so far as parts of the work may be in detail to the men actually at work upon it, and even such contracts should not be permanent in their character.

If a suitable lease can be effected, of which we have no doubt, we think the line between Greenfield and the Tunnel should at once be so far completed as to be brought into use. It will accommodate the people in the valley, develop the local traffic, and be of material use in constructing the Tunnel.

The cost of completing the whole work is so considerably beyond the unused portion of the two millions appropriation, that we have not thought it expedient to make any inquiry as to the price for which contractors would undertake any portion of the work.

EARNINGS.

There is no means of increasing the business and developing the resources and enterprise of a people which bears any comparison with that of railroads. No condition of civilized man is so low as not to respond to its electrifying influence.

Its power is so strong as to absorb the whole growth of a nation along its lines, and bring to a stand still all regions outside of its reach.

The best water powers will lie idle among a manufacturing people when unprovided with railroads, while the more expensive steam power is building villages all along their lines in places less favored by nature.

Local Business.

The fall of the Deerfield River along the line of the Troy & Greenfield Railroad, as shown by the profile, cannot be far from 600 feet. With one or two small exceptions, this large power is wholly idle; and with the exception of that at North Adams, it lies nearer to the food producing regions of the West than any other considerable water power in Massachusetts.

At the east end of the Tunnel the road comes within 15 or 20 miles of the extensive spruce lumber region of Southern Vermont, upon the Deerfield River. The county commissioners have already examined a route for a gradually descending road from the Vermont line to the Tunnel, and are ready to order its construction as soon as the Railroad is constructed to that point.

The outlet of this lumber now is over 25 to 30 miles of very hilly roads, to Brattleboro', North Adams, and Greenfield.

Large quantities of hemlock lumber, near the Tunnel, now cut merely for the bark, with railroad fa-

cilities, would become valuable for market. There are also here extensive deposits of soap-stone, which would soon contribute a large tonnage to the line.

The highway along the valley of the Deerfield is exceedingly hilly, sufficiently so to very much restrict the movement of freight, and discourage all business requiring it. As showing the amount moved by regular carriers, we insert the following statement, made to a committee of the Legislature at its last session: —

"To the Honorable the Legislative Committee on the Troy & Greenfield Railroad and Hoosac Tunnel:.

We, the undersigned, a committee chosen for that purpose, beg leave to submit to your board the following statement, showing the amount of tonnage hauled, and passengers carried over roads, to and from Greenfield and the points named along the line of the Troy & Greenfield Railroad, during the year 1861: —

TOWNS, &c.	Point of Shipment.	Amount of Tonnage.	Cost at present Prices.
Shelburne, ...	Shelburne Falls, . . .	3,696	$7,392 00
Coleraine, ...	" " . . .	1,862	3,284 00
Whitingham, ...	" " . . .	700	1,400 00
Halifax, ...	" " . . .	610	1,220 00
Buckland, ...	" " . . .	850	1,700 00
Ashfield, ...	" " . . .	800	1,600 00
East Hawley, ...	" " . . .	250	500 00
West "	Charlemont, ...	473	1,574 02
Charlemont, ...	"	1,625	5,301 25
Zoar, ...	Zoar, ...	425	1,700 00
Rowe, ...	"	450	1,800 00
Hoosac Tunnel, ...	Hoosac Tunnel, . . .	610	2,440 00
C. L. Spear, ...	Stage Proprietor, . .	. . . .	5,000 00
D. J. Kimball, ...	" " . .	. . . .	2,000 00
Total tonnage, ...		12,351	
Livery receipts on the above route, ...			5,000 00
			$41,911 27

The above includes merchandise and manufacturers' stock hauled by common carriers only. For the amount of produce of each town, and the prospective tonnage, we would respectively refer you to the statistics furnished and submitted to the Legislature of 1848.

In addition to the above towns, the entire business of Savoy, Reedsboro', and Wilmington, with a large portion of that of Conway, would be secured upon the completion of the railroad to the eastern end of the Hoosac Tunnel.

Signed, A. BOWEN,
S. D. BARDWELL,
E. M. WHITNEY,
EDWIN STRATTON,
HENRY C. BARDWELL."

If this line be completed immediately from Greenfield to the Tunnel, the business of this valley would be developing while the Tunnel was constructing, and by the time the Tunnel is completed it will have grown to considerable importance.

When the road is opened through the Tunnel, the flourishing town of North Adams would be brought into such direct communication with Boston as to furnish the line considerable business.

According to the census of 1860, the population lying west of Greenfield, within 10 miles of the Troy & Greenfield Railroad, on a distance of 44 miles, was 33,146. The population lying west of Springfield, and within 10 miles of a like distance upon the Western Railroad, was 42,058. Just west of this distance, on the Western Railroad, is the town of Pittsfield, having a population of 8,045, while the next town west, on the Tunnel route, is Pownal, in Vermont, having a population of about 2,000. If, during the eight years the Tunnel may be constructing, the population along the line increased 25 per cent., which is not far from the average for the State, it would then be 87 per cent. as large as that now on the Western Railroad, including Pittsfield.

With the large amount of water power upon this line, which eight years of railroad facilities may begin to develop, it does not seem unreasonable to estimate the local traffic at the same amount, in proportion to population, as that upon this part of the Western Railroad.

The local business of the Western Railroad, between Springfield and Albany, for the year ending November 30, 1861, was —

For local passengers, ...	$1,589 per mile.
" " freight, ...	2,460 " "

Estimating that for the Troy and Greenfield at 87 per cent. of this, it will be —

For local passengers, ...	$1,382 per mile.
" " freight, ...	2,140 " "

Through Passenger Business.

For through passenger business, the Western Railroad has great advantages over this line. With all the improvement which is likely to be made in the line through the Deerfield Valley, there will probably remain more curvature, strong enough to be embarrassing to quick trains, on this than on the Western route, perhaps enough to equal the disadvantage of their heavier grades, which, for passenger service, are not a very serious obstacle. Of the 200 miles from Boston to Albany, over 160 miles of it is double track, and the rest will probably be doubled before the Tunnel can be finished, if completed with the least practicable delay. This advantage, in amount of double track, will more than compensate for the difference in length, which, for the western passenger traffic, must be computed to Schenectady, where it is but 5 miles.

If no bridge should be built at Albany, and no change of cars be required on the Tunnel route east of Sche-

nectady, the physical advantages of the routes might be considered, so far as time is concerned, as nearly balanced.

The Western has another valuable advantage of a permanent character. The travel between Boston and Springfield is very large; this, added to the New York travel through that city, renders it profitable to run two, and sometimes three, express passenger trains per day, making but few stops on this half of the Albany route.

By taking the western passengers on these trains, they are enabled, without any extra expense, to give them great despatch over this half of their line.

The distance from Boston, via the Tunnel, is 18 miles nearer to Saratoga than via Albany; this will divide that travel, which, during the pleasure season, is quite important. Many passengers will go one way and come the other for the change of scenery and other causes, and the novelty of such a work as the Tunnel will attract some, while for many large towns, like Nashua, Lowell, Manchester N. H., Lawrence, Portsmouth, Portland, and large populous districts north and east of the line, the distance is so much in favor of this route as to control nearly their whole western travel. While, therefore, the Western Road will command the greater part of the through Boston passengers, there are other important sources from which the Tunnel line may reasonably expect a fair amount of long passenger traffic.

The long east and west passenger traffic received a shock in 1857, from which it had not recovered when the war broke out. This has since kept it in a state of unnatural depression.

There is so little that is certain, and so much that

must be conjecture, in making this estimate, that we are inclined to put it as low as $400 per mile; which, for 7 or 8 years hence, when the trade of the West may have doubled again, seems not unreasonable.

Comparison of Routes.

The great bulk of the freight carried between Boston and the West passes over the New York Central Railroad or through the Erie Canal, — much the larger portion over the railroad. The distance from Lake Erie to Boston, by rail, is 498 miles.

The distance between the waters of Lake Ontario, at Ogdensburg, and Boston, is 417 miles, or 81 miles shorter than from Lake Erie, at Buffalo. Against the cost of railroad transportation this extra distance of 81 miles from Buffalo, is to be put the cost by water through the Welland Canal, Lake Ontario, and the upper St. Lawrence, to Ogdensburg.

The difference between the rates of freight from the western lake ports to Buffalo, and the rates to Ogdensburg, will give this cost. This difference from the several ports is so nearly uniform, that the rates from one large shipping point will answer our purpose; and, taking flour as a fair sample, they are as follows: —

RATES OF FREIGHT ON FLOUR, PER BARREL,

From Detroit to Buffalo, and from Detroit to Ogdensburg, from 1858 *to* 1862, *inclusive, during open Navigation.*

	To Buffalo.	To Ogdensburg.	Difference.
1858.			
April, ...	15	40	25
May, ...	$13\frac{1}{2}$	36	$22\frac{1}{2}$
June, ...	$12\frac{1}{2}$	35	$22\frac{1}{2}$
July, ...	$12\frac{1}{2}$	32	$19\frac{1}{2}$
August, ...	$12\frac{1}{2}$	32	$19\frac{1}{2}$
September, ...	$12\frac{1}{2}$	32	$19\frac{1}{2}$
October, ...	14	35	21
November, ...	15	40	25
	Average	difference, 1858,	$21\frac{13}{16}$
1859.			
April, ...	11	30	19
May, ...	10	28	18
June, ...	10	26	16
July, ...	10	25	15
August, ...	10	26	16
September, ...	10	30	20
October, ...	15	38	23
November, ...	20	45	25
	Average	difference, 1859,	19
1860.			
April, ...	13	32	19
May, ...	12	30	18
June, ...	12	28	16
July, ...	10	26	16
August, ...	$17\frac{1}{2}$	35	$17\frac{1}{2}$
September, ...	20	48	28
October, ...	25	50	25
November, ...	$26\frac{1}{2}$	58	$31\frac{1}{2}$
	Average	difference, 1860,	$21\frac{3}{8}$

TABLE OF RATES OF FREIGHT, &c.—CONTINUED.

1861.	To Buffalo.	To Ogdensburg.	Difference.
April, ...	15	40	25
May, ...	15	40	25
June, ...	15	40	25
July, ...	15	38	23
August, ...	15	40	25
September, ...	15	45	30
October, ...	28	60	32
November, ...	$32\frac{1}{2}$	75	$42\frac{1}{2}$
	Average	difference, 1861,	$28\frac{7}{8}$
1862.			
April, ...	25	45	20
May, ...	20	40	20
June, ...	$17\frac{1}{2}$	40	$22\frac{1}{2}$
July, ...	$17\frac{1}{2}$	40	$22\frac{1}{2}$
August, ...	$17\frac{1}{2}$	40	$22\frac{1}{2}$
September, ...	$21\frac{1}{4}$	52	$30\frac{3}{4}$
October, ...	28	60	32
November, ...	$32\frac{1}{2}$	75	$42\frac{1}{2}$
	Average	difference, 1862,	$26\frac{19}{32}$
Average for the five years, cents, ...			$23\frac{44}{100}$

The average difference in the time of the voyage is about five days; the difference to Boston would be somewhat reduced from this, by the lesser distance from Ogdensburg than from Buffalo.

The difference in marine insurance is, in April, $\frac{55}{100}$ of one per cent.; in May, June, July, and August, $\frac{4}{10}$ of one per cent.; in September, $\frac{1}{2}$ of one per cent.; in Octo-

ber, $\frac{3}{4}$ of one per cent., and in November, 1 per cent.; averaging $\frac{55}{100}$ of one per cent., or about $3\frac{1}{2}$ cents per barrel. This, added to the difference in freight, gives a total difference of 27 cents per barrel. As the amount of flour moving in the early spring and the autumn months, when the rates are highest, is much greater than in summer, when they are lower, the real average is considerably higher than that stated.

As, however, 27 cents per barrel is much more than the cost of transportation over 81 miles of railroad, the route via the New York Central will cost the least to the carriers.

The Boston and Albany road is, therefore, the best freight line between Boston and the West, and it is with this that the Tunnel route should be compared.

Comparison of Tunnel with Western Line.

The system of equating the length of railroads, as we understand it, by adding a certain distance for each degree of curvature, or for each foot of inclined grade, has no practical value.

As a locomotive will haul but about half as much up a grade of 20 feet to the mile as upon a level, according to the equating theory a mile should be added for every twenty feet of rise in the grade, and this irrespective of its rate per mile. Thus, a railroad 100 miles long, with 40 miles of 18 feet rising grades, gives a total rise of 720 feet, which would be equal to an addition of 36 miles, making a total equal to 136 miles of level road; and a railroad 105 miles long, with 2 miles of 50 feet, 2 miles of 65 feet, 1 mile of 70 feet, and 3 miles of 80 feet rising grades, gives a total rise of 540 feet, which would be equal to an addition of 27 miles, making a total equal to 132 miles of level road.

According to this theory, the road of 105 miles, with a maximum grade of 80 feet per mile, is 4 miles shorter than a road of 100 miles, with a maximum grade of 18 feet per mile.

This theory is equally fallacious when applied to equating the distance by the curvature. The curvature of the two lines will not be sufficiently different to materially affect their relative capacity for transportation of freight.

The steepest grade upon a line is not always the one which limits the weight of the trains. It must have considerable length, or be so situated that a train will have to pass a part of it without the aid of the momentum with which it is approached.

If the motive power upon a road doing a large freighting business is worked in more than one division, the effect of the controlling grades upon the traffic must be considered separately upon the different divisions. A convoy of trains may require 5 locomotives upon the steeper grades, where but 2 or 3 would be used to take them over the divisions having the lighter grades.

When the traffic in the different directions is very unequally balanced, requiring many empty cars to be run in one direction, it may be that a long grade, rising in the direction of the heavy traffic, will be the controlling grade of the division, though a much steeper and longer grade rises in the opposite direction.

It is evident that in doing the local, or short business, when cars are constantly being added to and taken off the trains, the average load will be far below the maximum power of the locomotives.

The irregularities of business will reduce the average weight of the trains in the long traffic somewhat, but by judicious management the through freight, if it be considerable, can be worked in very nearly full trains.

In considering the effect of the grades upon the traffic, the average, and not the maximum trains, should be taken as the basis.

It is better to obtain the probable average of the loads, and some other data, from actual experience, when it can be had, rather than from estimate. The doings of the Western Railroad would form the best basis, but they probably have not kept the average loads moved on their different divisions separate from each other. Another long road, further west, in the same line, furnishes the following facts from the freight business of their last year: —

Average No. of tons of freight per train, per mile, eastward,	192.29
" " " " " " " " " " westward,	50,01
" " " " " " " " " "	121.15
Proportion of whole tonnage eastward, per cent., ...	79.36
" " " " westward, " "	20.64
Average weight of freight engines in service, ...	53,000 lbs.
" " " " " and tender in service,	78,000 "
" " " " trains eastward, locomotive and cars included, about	406 tons.

The proportions between the eastward and westward through tonnage on the Boston and Albany line has been, for the aggregate of the last four years, $79\frac{59}{100}$ per cent. eastward, and $20\frac{41}{100}$ per cent. westward; a proportion so nearly like the one quoted above, that the first may safely be taken as the relation between the east and west through tonnage in the comparisons which are to follow.

Assuming that the friction of moving the trains is equal to a grade of 20 feet per mile, which is about right upon a fair track, and the average load per train on the road above quoted would be varied by the grades on the Tunnel and Western routes, as shown in the table on page 75.

TUNNEL LINE.

DIVISIONS.	Boston to Fitchburg.	Fitchburg to Greenfield.	Greenfield to N. Adams.	N. Adams to Troy.
Length in miles, ...	49.65	55.5	37.02	$47\frac{5}{10}$
Controlling grade eastward, feet, .	$34\frac{3}{10}$	$48\frac{1}{4}$	40	$39\frac{6}{10}$
" " westward, " .	$40\frac{7}{10}$	58	$58\frac{6}{10}$	$26\frac{4}{10}$
" " of traffic, " .	$34\frac{3}{10}$	$48\frac{1}{4}$	40	$39\frac{6}{10}$
Average load eastward, tons, . .	183	142	164	165
" " westward, " . .	47	37	43	43
" " in both directions, .	115	89	103	104

Distance from Boston to Troy, ... 189 miles.
Average load over the whole line, ... 102 tons.

BOSTON AND ALBANY LINE.

DIVISIONS.	Boston to Worcester.	Worcester to Springfield	Springfield to Pittsfield.	Pittsfield to Albany.
Length in miles, ...	44	54	53	49
Controlling grade eastward, feet, .	30	60	$75\frac{1}{2}$	45
" " westward, " .	30	$48\frac{84}{100}$	83	45
" " of traffic, . . .	30	60	$75\frac{1}{2}$	45
Average load eastward, tons, . .	201	118	95	150
" " westward, " . .	52	30	25	39
" " in both directions, .	126	74	60	95

Distance from Boston to Albany, ... 200 miles.
Average load over the whole line, ... 86,87 tons.

For Lines and Profiles, see plates D and E.

Only a small part of the working expenses are increased by an increase of the controlling grades. Nearly the whole of the cost of motive power, with the exception of fuel and water, does so increase. The nearer a road is to level the more fuel the engines, when full loaded, will consume per train per mile, because they will be working to their full power all the time; while on a heavily undulating road, they work to their maximum only up the controlling grades, and much of the time on the down grades fuel is consumed very slowly; therefore, the heavier the controlling grade the less the fuel used per train per mile, but of course the more per ton per mile. On the very steep grades there is some extra wear of cars and rails, perhaps enough to balance the decreased consumption of fuel, leaving the extra expense per ton per mile equal to the cost of motive power.

The cost of this depends very largely upon the price of fuel; upon these lines it may vary from 25 to 31 per cent. of the whole cost of operating, and a fair average for the motive power would not be far from 28 per cent.

It has been found that the locomotive which would haul an average of $86\frac{87}{100}$ tons upon the Western Railroad route, would take 102 tons, or $17\frac{4}{10}$ per cent. more, upon the Tunnel route.

A net saving is therefore made of 28 per cent. of $17\frac{4}{10}$ per cent. or about 5 per cent. of the total cost of transportation, by reason of the easier controlling grades of the Tunnel route. This, represented by miles, would reduce the distance from 189 to $179\frac{1}{2}$ miles, or, say 180 miles, and reduce the general cost of transportation between Boston and the Hudson River 10 per cent. We are aware that from the east side of the river at

Albany to Schenectady the distance is but $17\frac{1}{2}$ miles, while from Troy to Schenectady it is 21 miles, or $3\frac{1}{2}$ miles further. The rates from the west, on the New York Central Railroad, however, have always been the same to both places; and even should a bridge be built across the river at Albany, it will, probably, be as cheap for that Company to send a part of its business to Troy as to incur the inconvenience of passing it through the crowded Albany terminus.

The distance from the West to Troy, by canal, is seven miles less than to Albany.

The cost of transportation from the West to these two cities is quite uniform, and for practical purposes may be considered alike.

Tunnel Line Compared with Line to New York.

Having shown the relative freighting capacity of this line with that of others leading to Boston, it remains to compare it with the lines leading to New York, to show what effect, if any, it may have upon the relative position of these two cities for trade with the West, and as places of export for Western produce.

The terminal expenses of the Hudson River Railroad, necessarily incurred at New York, are very large. The great amount of hauling by horse power, and doing so extensive a business, with their grounds and tracks crossed by so many streets, in such a thronged city, must add quite enough to the expense of working their road to neutralize the economy of their more level grades as compared with the Tunnel route, and leave them no advantage but in their lesser distance.

The distance from Albany to New York is 144 miles,

or 45 miles less than from Troy to Boston by the Tunnel route.

Even with the use of horse power, it has not been found practicable to bring their freight trains within reasonable reach of the principal exporting facilities of the city. A long and very expensive cartage intervenes. A large portion of the grain arriving by the Hudson River Railroad is in bags, and the cost of cartage from their freight station to the storehouses is $1.50 per load, of 35 bushels, or say 4¼ cents per bushel, or $1.43 per ton. There are, besides this, the storage charge, of 1 to 1½ cents per bushel per month, the cost for labor of 1 to 1½ cents per bushel, and, when shipped, another cartage charge of 50 cents per load, or 47 cents per ton.

When grain arrives in bulk, which is not usually the case, it is lightered from the depot to the storehouse or vessel.

When it is delivered direct from the railroad to the vessel, which is often the case, the cost of storage and short cartage is saved.

On flour, the cost of cartage from the station to the warehouses is 12½ cents per barrel, or $1.15 per ton. Cost of storage, 3 cents per barrel per month; of labor, 2 cents or more per barrel; and cartage from warehouse to vessel, from 3 to 5 cents per barrel. When it is lightered from station to storehouse or vessel, the cost is 9 cents per barrel.

The cartage from the New York station of the Harlem Road is considerably less than from the Hudson River Road, but the Harlem is about ten miles longer, and has much heavier grades. The cost from Albany to the ship's side at New York is probably very nearly alike over these two roads.

We have made our comparison with the Hudson River Road, because the bulk of the business is done by that line.

The entrance of the Tunnel line into Charlestown is directly upon very extensive wharves, belonging to the Fitchburg Railroad Company, along side of deep water, and tracks are already extended to a large amount of similar wharf property belonging to private parties. Produce could here be unloaded from the cars directly into vessels, or into warehouses, from which no cartage would be required to the ship's side; and even from the warehouses, as now located, but a little back from the front of the wharf, the cost of cartage would be quite insignificant.

The difference in cost of moving produce from the New York station of the Hudson River Railroad to ships, for export, and doing the same at the Fitchburg station in Charlestown, must be an average of more than a dollar per ton. This is much greater than any possible difference in cost between the railroad transportation from Troy to Boston and from Albany to New York; for the difference in distance is but 45 miles, and the difference in cost on the long traffic should not be above 60 cents per ton, if even so much.

During open navigation on the Hudson River, the cost of transportation between Albany and New York is very light. That which arrives at Albany from the West by canal, generally goes to New York without change at Albany. That which arrives by rail, and a small portion of that arriving by canal, is taken to New York by steamers, and by barges towed by steamers; the heavier produce mostly by barges.

The cost of this transportation by barges is given in the following statement: —

STATEMENT SHOWING THE AVERAGE RIVER FREIGHT ON FLOUR AND WHEAT, FROM ALBANY TO NEW YORK, IN MONTHLY STATEMENTS, FROM 1856 TO 1862, INCLUSIVE, BY BARGES TOWED BY STEAM.

MONTHS.		1856.		1857.		1858.		1859.		1860.		1861.		1862.	
		Flour per Bbl., in Cents,	Wheat per Bush. in Cents.	Flour per Bbl., in Cents.	Wheat per Bush. in Cents.	Flour per Bbl., in Cents.	Wheat per Bush., in Cents.	Flour per Bbl., in Cents.	Wheat per Bush., in Cents.	Flour per Bbl., in Cents.	Wheat per Bush., in Cents.	Flour per Bbl., in Cents.	Wheat per Bush., in Cents.	Flour per Bbl., in Cents.	Wheat per Bush., in Cents.
March, . . .	B.	. . .	. . .	10	. . .	8	. . .	8	. . .	8	. . .	10	3	12½	3
April, ...	B.	9½	. . .	10	. . .	8	. . .	8	. . .	8	. . .	10	3	12½	3
May, ...	B.	8	2¾	10	. . .	6	2	6	2	6	2	8	3	10	3
June, ...	B.	7½	2½	9	3¼	6	2	5	. . .	6	2	8	3	10	3
July, ...	B.	7¾	2¾	9	3¼	6	2	4	. . .	6	2	8	3	10	3
August, . . .	B.	7½	2½	8	2½	6	2	3¾	. . .	7	2½	8	3	10	3
September, . .	B.	7½	2½	8	2½	6	2	4½	. . .	10	3½	12	3½	12	4
October, . . .	B.	10	4	8	2½	8	2½	6	2	11	4	14	4	14	4½
November, . .	B.	12	5	8	3	8	2¾	8	2¾	13	5	16	5	16	5
December, . .	B.	15	6¼	10	4	10	4	10	. . .	13	5	16	5	18	5

Insurance upon the North River is nominal. Steamboat and barge lines are regarded by the public, and by the lines themselves, as all rail in this respect. When any insurance, which is rare, is put upon a cargo of wheat or flour, it is not for more than one fifth of its value, on account of the probability of saving almost the entire cargo in case of accident.

The through rate, by the canal, from the West to New York, is usually higher than the rate to Albany, by the amount of the barge rate on the river.

If produce coming through from the West does not incur a transshipment expense at Troy, something will be saved in that way; for this expense is usually attached to the barge freight, and is so much above the rates given in the preceding statement. The storehouse, and other expenses at Charlestown, would probably be considerably less than in New York, still leaving, however, a margin in favor of New York, to go against the lesser distance from Boston to Liverpool; though we think not nearly so great a margin as there is in favor of Boston, in the winter months, and not greater than the enterprise and interest of Boston merchants should induce them to so far overcome as to command a share of this export trade.

In making an estimate of the amount of through business likely to be done eight years hence, the natural increase should be carefully considered.

It would be a work of much labor to trace all the produce which has been received for several years from such portions of the West as would naturally outlet in part over this line, and separate that which has been exported from the rest, and thus reach the home consumption contributed by that region. We shall therefore consider flour as a fair sample of the produce trade.

It is strongly significant of the growth of this business that the through freight of the Boston and Albany line has increased very largely, notwithstanding the opening of several new lines competing for the same traffic. This is shown by the following table : —

STATEMENT OF THE FREIGHT BUSINESS BETWEEN ALBANY, BOSTON, AND BRIGHTON, FROM 1843 TO 1862, INCLUSIVE.

Year.	No. of Tons.	Amount received.	REMARKS.
1843.	26,585	$113,807	
4.	35,470	162,804	
5.	42,573	185,278	
6.	52,695	229,444	
7.	107,655	455,563	
8.	82,699	364,032	
9.	79,945	348,187	
1850.	80,476	350,259	Route from Troy, via Rutland, opened through.
1.	68,130	312,698	Ogdensburg route opened.
2.	63,820	256,112	
3.	86,180	330,960	
4.	91,046	393,142	
5.	98,486	482,695	
6.	117,249	664,644	
7.	80,828	446,484	
8.	100,802	443,480	Through freighting, via Grand Trunk and Portland, commenced.
9.	98,489	375,582	
1860.	123,683	460,228	Providence and Erie began through freighting.
1.	172,958	585,486	
2.	176,805	675,321	

To dispose of the minor irregularities of the traffic, if we divide these twenty years into four periods, of five years each, the results will be as follows: —

End of Period.	No. of Tons.	Per cent. of Increase from last Period.	Amount Received.	Per cent. of Increase from last Period.	Average Rate per Ton.
1847.	264,978	. . .	$1,146,896	. . .	$4 33
1852.	375,070	41	1,631,288	43	4 35
1857.	473,789	26	2,317,925	42	4 89
1862.	672,737	42	2,540,097	10	3 77

Had no new routes competing for the same business been opened, these figures would be a fair indication of the growth of the carrying trade between Boston and the West, but during this period the four new lines noted in the table of Albany and Boston business have been opened, and for a few years before the war the Baltimore & Ohio and Pennsylvania Central lines were also sharing the traffic, making six new routes. These are all much less direct than the Albany and Boston line, and though in the last five years they have carried more than half the flour, they have probably carried less than half the gross tonnage moved.

The flour brought to Boston in the last 5 years by the Boston and Albany line was	217,961 tons.
The remaining through tonnage of this line was . .	454,776 "
The flour brought in the same time by the four competing lines named in the table was	241,217 "
Estimating the remaining through tonnage of all the competing lines at only one third of the Boston and Albany, which we think quite small enough, and it would be, say, ...	151,592 "
Whole amount, ...	1,065,546 "

making a total for the 5 years of 1,065,546 tons, which is about 400 per cent. increase over the tonnage 15 years before, or over the 5 years ending with 1847. This is equal to 58 per cent. increase for each period of 5 years.

This increase has not resulted from any improvement in the lines of communication, for all the new lines have been longer and far less efficient carriers than the old one. We have no doubt that had one of these lines been shorter, or even as short, as the Albany and Boston line, the increase would have been greater.

At this rate, the increase for the next eight years would be about 110 per cent. over the business of 1862.

If we estimate the increase to be but 60 instead of 110 per cent. by the time the Tunnel is completed, the total would then be as follows:—

Boston and Albany through freight for 1862 was .	176,805	tons.
The same relative proportion for the other lines as was before estimated for the 5 years, would give for them, say, ...	103,258	"
Total present tonnage, ...	280,063	"
Add 60 per cent. for the increase, ...	168,038	"
Total amount of tonnage for 8 years hence	448,101	"
If the Tunnel line should get one third as much as this, at ten per cent. less rate of freight than the Albany and Boston line received in 1862, it would have a tonnage of	149,367	"
and receive on through freight the sum of	$513,524 00	
which would be per mile, ...	$2,716 00	

It will be observed that the estimate of increase is not based upon any improvement in the line of communication, but is only $\frac{60}{110}$ of the past increase, and this has been quite as rapid in late years as formerly. If, as we think we have shown, this line should be the means of increasing the exports of Western produce

from this port, the earnings from this source will be so much additional revenue to make up any deficiency resulting from an over estimate of the other business of the line.

If no Western produce had been heretofore exported from Boston, we should be some in the dark as to the influence which a certain amount of improvement in the carrying lines to the West would produce. Enough, however, has been exported to show its practicability, and to indicate that a moderate reduction in freight to this point would make it a profitable and prosperous business.

The following table shows the amount of flour received in Boston from the West, and the amount exported from 1848 to 1862, inclusive, (see page 86): —

Only a small portion of the amount exported was coastwise, the greater part having gone to foreign ports.

The rates of freight to Liverpool, as compared with New York, and with Portland in the winter, since the Grand Trunk Railway has been opened through, are shown in the following table (see page 87): —

TABULAR STATEMENT OF THE ARRIVALS AND EXPORTS OF FLOUR AT BOSTON,

IN BARRELS.

	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Western Railroad,	364,373	343,507	367,808	242,466	250,811	277,014	228,801	341,852	286,646	217,231	278,438	266,452	302,462	641,824	543,227
Northern "	. . . .	. . . .	. . . .	41,159	45,669	78,446	101,077	37,004	55,953	110,232	159,111	96,469	60,587	101,680	186,437
Fitchburg "	. . . .	200	9,026	118,150	148,292	66,885	71,243	42,913	26,632	27,750	53,209	45,908	35,737	127,301	96,299
Boston & Me. "	. . . .	. . . .	. . . .	10,238	98,817	182,778	103,421	106,689	146,360	117,346	15,694	6,808	14,808	28,549	36,833
Fall River "	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	1,173	. . . .	. . . .
Providence "	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	85,492	165,718	170,223
New York, . . .	119,281	107,016	82,213	84,450	57,997	44,677	27,192	61,409	31,914	71,621	87,045	64,667	25,381	14,084	8,741
Albany, ...	75,463	57,916	37,557	31,676	15,065	7,271	. . . .	2,093	280	1,200	8,986	810	260	980	1,475
Portland, ...	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	15,032	74,173	217,897	167,994	271,530
All other sources,	376,461	517,670	264,544	245,373	279,803	278,891	235,356	420,969	461,665	503,643	610,124	493,899	420,935	185,869	51,067
Totals, ...	935,578	1,026,309	761,148	773,512	896,454	935,962	767,090	1,012,929	1,009,450	1,049,023	1,227,639	1,049,186	1,164,732	1,433,999	1,365,832
Amount exported,	129,678	153,933	115,316	177,346	269,771	382,305	188,353	159,084	198,081	184,597	196,862	164,875	234,616	389,730	555,591

STATEMENT OF COMPARATIVE RATES OF FREIGHT ON FLOUR, PER BARREL, IN CENTS, FROM NEW YORK AND BOSTON BY SAILING VESSELS, AND FROM PORTLAND BY STEAMERS TO LIVERPOOL, FROM 1856 TO 1862, INCLUSIVE.

MONTHS.	1856.			1857.			1858.			1859.			1860.			1861.			1862.		
	From New York.	From Boston.	From Portland.	From New York.	From Boston.	From Portland.	From New York.	From Boston.	From Portland.	From New York.	From Boston.	From Portland.	From New York.	From Boston.	From Portland.	From New York.	From Boston.	From Portland.	From New York.	From Boston.	From Portland.
January,	75	60	. .	36	48	. .	36	. .	. .	. .	24	30	34	30	40	75	70.5	55	75	75.3	50
February,	62	60	. .	54	60	. .	35	36	. .	. .	24	30	. .	. .	45	80	70	55	50	70	50
March,	62	60	. .	34	60	. .	31	. .	. .	. .	. .	30	53	. .	40	75	71.5	55	44	50	60
April,	62	60	. .	. .	60	. .	28	. .	. .	. .	. .	30	. .	48	40	75	65	55	56	50	60
May,	50	60	. .	. .	60	. .	50	. .	. .	. .	. .	. .	50	. .	. .	63	64.6	. .	65	63	
June,	52	48	. .	. .	48	. .	31	24	. .	. .	36	. .	50	48	. .	50	58.7	. .	63	65	
July,	66	48	. .	. .	36	. .	31	36	. .	. .	. .	. .	56	48	. .	50	53.3	. .	94	83.3	
August,	33	54	. .	. .	48	. .	50	36	. .	. .	18	. .	62	. .	. .	75	53.5	. .	100	99.4	
September,	34	48	. .	30	48	. .	31	36	. .	31	36	. .	81	. .	. .	63	47.8	. .	100	88.5	
October,	50	48	. .	51	48	. .	29	. .	. .	34	. .	. .	81	. .	. .	75	53.5	. .	100	94.5	
November,	50	48	. .	55	60	. .	. .	. .	30	50	. .	30	100	72	55	88	60	50	63	80.5	65
December,	50	66	. .	50	72	. .	34	. .	30	50	. .	30	83	84	55	50	72	50	50	97.2	65
Average,	$53\frac{10}{12}$	55	. .	$44\frac{2}{7}$	54	. .	$35\frac{1}{11}$	$33\frac{3}{5}$	30	$41\frac{1}{4}$	$27\frac{3}{5}$	30	65	55	$45\frac{5}{6}$	$68\frac{1}{4}$	67	$53\frac{1}{3}$	$71\frac{2}{3}$	$76\frac{8}{10}$	$58\frac{1}{3}$

With a moderate amount already exporting to Liverpool, at rates averaging not more below the rates from New York than the distance from Boston to Liverpool is relatively less, it would seem as if the increased facilities offered by the Tunnel line should put it in the power of the Boston merchants to build up a large and profitable trade from this source.

The manufacturing countries of the world are getting farther every year from the ability to produce their own food. Our western prairies are destined to permanently supply a large part of their growing deficiency, and the transportation of food is to be one of the great elements of our nation's prosperity. A successful engagement in this trade may therefore be counted as a permanent source of prosperity to our shippers, our city, and our State.

The other railroad companies forming with this the Tunnel route, mindful of their own interest, and disposed to recognize, in a substantial manner, the benefits they will receive if the Tunnel be completed, have executed a contract, of which the following is a copy: —

Contract.

Whereas, for many years, great efforts have been made by the Troy & Greenfield Railroad Company to finish their railroad and construct the Hoosac Tunnel, which, notwithstanding the aid granted to them by the Commonwealth of Massachusetts, they have found themselves wholly unable to accomplish, the means and credit of the Company having become exhausted, and further progress having stopped nearly two years ago, with no part of the road east of the Tunnel opened for

use, and the Tunnel but little more than commenced; and,

Whereas, it is of the utmost importance to the rest of the railroads forming the line from Boston via Fitchburg and Greenfield to Troy, that the said Troy & Greenfield Railroad and Hoosac Tunnel should be completed, by which they may become part of a short through line to the West; and,

Whereas, the cost of constructing the said Hoosac Tunnel will be very large, and to a great extent uncertain in amount, and, at the least, wholly disproportionate to its revenue-earning value when considered as a piece of railroad of only its real length, while it will be of such vast benefit to the said whole line of railroads from Boston to Troy, that its construction is warranted as a commercial undertaking;

Nevertheless, the railroads so interested in and desirous of its construction, and to receive such large benefits therefrom, are not in a position to undertake it, or to render adequate aid to the Troy & Greenfield Railroad, to enable that Company to construct it, but in lieu thereof are willing to pay such just proportion of their earnings from business which may pass through said Tunnel, or over said road, as shall be an equitable return for the benefits received.

Now, therefore, the Vermont & Massachusetts Railroad Company, and the Fitchburg Railroad Company, corporations created by the laws of Massachusetts, and the Troy & Boston Railroad Company, a corporation created by the laws of New York, in consideration, that the Commonwealth of Massachusetts shall construct, or complete, or cause to be constructed or completed, the said Troy & Greenfield Railroad and Hoosac Tunnel, hereby severally, and not jointly, agree and bind them-

selves and their assigns to the Commonwealth of Massachusetts, to pay to the said Commonwealth certain sums of money, as follows: —

Each of said Companies hereby agrees to pay to said Commonwealth twenty (20) per cent., or one fifth of all its gross earnings, upon such passenger and freight business as shall pass upon or over any part or the whole of the said Troy & Greenfield Railroad. For example: If either of said Companies shall transport upon their railroad a ton of freight, and receive as their gross earnings for the same the sum of one dollar and fifty cents, and said freight shall pass over said Troy & Greenfield Railroad, or any part thereof, either before or after such transportation, then this said Company shall pay to said Commonwealth the sum of thirty (30) cents, and in the same proportion for earnings from passengers, or for a greater or less amount of earnings from passengers or freight which passes over any part of said Troy & Greenfield Railroad.

Provided, that if and whenever the payment of the said twenty (20) per cent., together with any similar or other payments which may have been actually received from any and all other sources, on account of earnings, shall make the net earnings upon the cost of the said Troy & Greenfield Railroad and Hoosac Tunnel, and the equipment thereof, more than six (6) per cent. in any year, or the gross earnings more than thirteen (13) per cent. for any year, then and in that case the said twenty per cent. may be reduced, for the time being, to such a less per cent. as, together with any similar or other payments which may have been actually received from any and all other sources on account of earnings, shall make the said net earnings six (6) per cent., or the gross earnings thirteen (13) per cent.;

on the cost of the said Troy & Greenfield Railroad and Hoosac Tunnel, and the equipments thereof.

Provided, that whenever the earnings of the said Troy & Greenfield Railroad shall, without the payments therein provided for from the respective Companies, amount for four (4) consecutive years to not less than six (6) per cent. net, or thirteen (13) per cent. gross, in each separate year, upon the cost of constructing the said Troy & Greenfield Railroad and Hoosac Tunnel, and the equipments thereof, then the payments herein provided for shall forever cease.

So far as this agreement is concerned, the cost of the said Troy & Greenfield Railroad and Hoosac Tunnel, and equipments thereof, shall be estimated to be, on the first day of January, A. D. 1863, the sum of nine hundred and sixty-eight thousand eight hundred and sixty-two dollars ($968,862), to which shall be added the cost of their completion, as it shall be from time to time expended; and there shall also be added to the cost of construction the interest, at the rate of five (5) per cent., as it shall from time to time be paid on the bonds, which may be issued by the Commonwealth to raise money to pay for construction or interest; and upon such money as may not be raised by the issue of bonds, the interest at the same rate of five (5) per cent. shall be charged into the cost, on the first day of January and July in each year.

Provided, that no interest shall be charged into the cost of the works after eight years from the date hereof.

Provided, that all sums of money received as profits from operating or working a part of the said Troy & Greenfield Railroad, and for rents of the same before business shall commence to pass through the said

Tunnel, shall be deducted from the cost, as the same may from time to time be received.

And should it so happen after business shall have begun to pass through said Tunnel, that the net earnings, over and above all expenses, together with the payments which may be received under the provisions of this contract, amount, in any one year, to less than five (5) per cent. net, or eleven (11) per cent. gross, upon the cost of the said Troy & Greenfield Railroad and Hoosac Tunnel, together with the equipments thereof, then and in any such case the deficit, or amount which said net earnings and payments are below five (5) per cent. net, or eleven (11) per cent. gross, shall be added to the said cost, and the cost so increased shall be then reckoned, so far as this agreement is concerned, as the cost of the said Troy & Greenfield Railroad and Hoosac Tunnel, together with equipments thereof.

Settlements of accounts, under this provision, shall be for years ending December 31st, and for the first settlement, which may be for a fraction of a year, the interest shall be charged at the same pro rata rate for the said fraction of a year.

It is understood, that for such business as originates upon the Troy & Greenfield Railroad at or west of North Adams, and passes westward over any part of the Southern Vermont or Troy & Boston Railroads, and for such business as comes from the Troy & Boston or Southern Vermont Railroads and does not pass upon the Troy & Greenfield Railroad any further eastward than to North Adams, the Troy & Boston Railroad Company shall not, by reason of this contract, be required to make any contribution to the Commonwealth of Massachusetts.

It is hereby agreed, by the said several corporations, that they will pay and receive, as their respective proportions of the gross earnings on any freight or passengers which pass over the said Troy & Greenfield Railroad, or any part thereof, and over any part or the whole of their several railroads, their pro rata proportion on each passenger or parcel of freight, which shall be computed and divided according to the distance it may have been carried upon the line between Boston and Troy; and from the gross earnings, so ascertained, the twenty (20) or other per cent. aforesaid is to come and be paid to the said Commonwealth, except as herein before provided in case of Troy & Boston Railroad Company.

The payment of the said twenty (20) or other per cent. to commence when business begins to pass through the Tunnel, though the said Tunnel, or road and equipments, may not have been fully completed.

Such payments to be made monthly, as soon as practicable after the close of each month, and in any event before the close of the next succeeding month from the one for which the payment is due; and the books of said companies, in which are kept the earnings accounts, to be subject to the inspection, at any time, of a proper officer of the Commonwealth.

It is hereby agreed that, in the event of the Troy & Greenfield Railroad Company, or any other party, redeeming the said Troy & Greenfield Railroad and Hoosac Tunnel, and equipments, from the claims of the Commonwealth, the Commonwealth may, or may not, at its election, transfer to the party which should redeem, all its rights under this instrument, or continue to hold the same for its own benefit.

And the said Troy & Boston Railroad Company

agrees that, for the purposes of this contract, the entire distance from the State line of Massachusetts to the city of Troy shall be deemed and treated a part of its road, although a portion thereof is leased by it from another corporation.

In witness whereof, the parties have hereunto affixed their hands and seals. The said Fitchburg Railroad Company, this 23d day of February, A. D. 1863, by their President, duly authorized therefor; and the said Vermont & Massachusetts Railroad Company, this twentieth (20th) day of February, A. D. 1863, by their President, duly authorized therefor; and the said Troy & Boston Railroad Company, this 18th day of February, A. D. 1863, by their President, duly authorized therefor.

TROY & BOSTON R. R. COMPANY,
By D. THOS. VAIL, *President.*
In presence of [SEAL.]
D. W. MOSELY, as to signature
D. THOS. VAIL, *President.*

THE FITCHBURG RAILROAD COMPANY,
By JNO. J. SWIFT, *President.*
Witness to the signature of [SEAL.]
JOHN J. SWIFT, *President,*
A. CHAPMAN.

VERMONT & MASSACHUSETTS R. R. CO.,
By ROBERT HALE, *President.*
B. D. LOCKE, witness to signature of [SEAL.]
ROBERT HALE, *President.*

We do not know that this contract requires any explanation from us, except the simple statement that 6 per cent. upon the total estimated cost of $5,719,330 is equal to 8 per cent. upon $4,287,833, the amount required to complete the work; and we now give a summary of the

Estimated Earnings.

From local passengers, $1,382 per mile, for 44 miles, .	$ 60,808
" " freight, $2,140 per mile, for 44 miles, . .	94,160
" through passengers, $400 per mile, for 44 miles, .	17,600
" " freight, $2,716 per mile, for 44 miles, .	119,504
Mails and express, &c., ...	10,000
Total earnings on line, ...	$302,072
Deduct 55 per cent. for operating expenses, ...	166,139
Net earned on road, ...	$135,933
Estimating the local passengers to pass an average of 30 miles upon the other roads in the line, and the local freight an average of 60 miles, the payments under the contract with the other companies will be as follows: —	
On local passengers $\frac{1}{5}$ of 30 miles = 6×1,382 =. . .	$ 8,292
" " freight $\frac{1}{5}$ of 60 miles = 12×2,140 = . . .	25,680
" through passengers $\frac{1}{5}$ of 145 miles = 29×400 = .	11,600
" " freight $\frac{1}{5}$ of 145 miles = 29×2,716 = . .	78,764
Total net earnings and receipts, ...	$ 260,269
This is $4\frac{55}{100}$ per cent. upon the whole estimated capital and interest of	$5,719,330
It is $6\frac{7}{100}$ per cent. upon the estimated capital and interest required to complete the Road and Tunnel, which is	$4,287,883
The amount already advanced by the State, and the interest upon it, included in the "whole estimated capital," is	$1,431,447

This amount, and the future interest upon it, would be practically sunk if the work should not be further prosecuted.

If, after this line is opened, the Boston merchants do their share of the work, which we think their interest will prompt them to do, the increase of business be-

yond this estimate should be large and satisfactory, not mainly by withdrawing traffic from the old line, but by that increase of business which always keeps pace with increased facilities.

CONCLUSION.

The State of New York built the Erie Canal, and its influence has reduced the price of food in the smallest hamlet of Great Britain.

The sixty-two millions spent upon her canals have given that State the leading position in this country. Without them, the Hudson River, draining an insignificant area, could have built but a moderate city at its mouth.

The level grades and direct line of the New York Central Railroad did not prevent the State from largely aiding in the construction of the Erie Railroad, to which its citizens added some thirty-eight millions, from higher motives and a broader policy than mere investing for dividends; making large personal sacrifices to force that work through a very difficult country, and provide one more inlet to their city for the increasing products of the West.

Pennsylvania has invested large sums in public works, to shorten the distance between Philadelphia and the same producing regions; and that city and her citizens have but lately completed a noble line, of more than 800 miles, from Philadelphia to Chicago.

The State of Maryland and city of Baltimore provided more than twelve millions of the capital to construct the Baltimore & Ohio Railroad over and through the mountains to the West.

These States and cities have received such large and constantly increasing benefits from these public works, as to render their solid advancement in wealth and prosperity almost without parallel.

Aside from numerous smaller lines, the principal works constructed to connect these cities with the West have cost nearly as follows: —

New York Canals, ...	$62,000,000	
Hudson River and New York Central Railroads, ...	45,000,000	
New York & Erie Railroad, ...	39,000,000	
		$146,000,000
Pennsylvania railroads and canals constructed by the State, ...	$34,000,000	
Less, received for works sold to the Pennsylvania Railroad, ...	7,500,000	
	$26,500,000	
Pennsylvania Central Railroad, . . .	32,000,000	
		$58,500,000
Baltimore and Ohio Railroad, ...		30,000,000
Total for the three cities, ...		$234,500,000

In these public works the State of New York has invested about	$65,000,000
The State of Pennsylvania and city of Philadelphia, about	$40,000,000
The State of Maryland and city of Baltimore about	$12,000,000
And individuals about	$117,500,000
For the purpose of drawing through its territory and to its cities a portion of the carrying trade of the West, there has been expended in public works in Canada not far from	$75,000,000
To connect Boston with the West, the Albany and Boston line was built at a cost of about . . .	$16,000,000
The State of Massachusetts furnishing of the capital	$5,000,000
And individuals and the city of Albany about . .	$11,000,000

A very large proportion of these vast expenditures, to take the Western trade to other cities, has been incurred since Massachusetts made her only successful effort; and while the avenues to other cities have been widening, deepening, and growing more numerous, those to Boston have not been improved.

It has naturally resulted that the relations between the West and the other Atlantic cities have grown more and more intimate, and those with Boston less so, as the relative distance between Boston and the West has year by year increased.

We cannot but suggest, that Massachusetts can hardly look with indifference upon the gradual waning of her relations with those who, in the early future, must control the country.

The soil of our State requires a home market for its products, which our manufactories only can supply.

Both our agriculture and our commerce depend upon our manufactures, and it is of great importance to this interest that it be in a position to exchange its goods for the food it must buy with the least expenditure in transportation, for this both reduces the price of its goods and raises the cost of its food.

Every measure, therefore, which will shorten the distance between Boston and the West should receive our careful consideration, for it will aid our commerce, our manufactures, and, indirectly, our agriculture.

The coastwise trade of Boston would feel the influence of having cheaper food to distribute.

A share in the export of Western produce, which now goes to the north and south of us, would be within our reach.

The construction of the New York & Erie, the Pennsylvania Central, and the Baltimore & Ohio Railroads,

all shorter from the West to the seaboard than the New York Central, have not taken away its business, or sensibly diminished its prosperity.

The vast tonnage moving over the newer constructed lines has not prevented a very large and continuous increase in that of the New York Central, the through tonnage upon which has, for several years, been as follows: —

Years ending September 30, —

1856,	253,288 tons.
1857,	292,877 "
1858,	312,408 "
1859,	348,079 "
1860,	412,526 "
1861,	551,897 "
1862,	777,190 "

Why should it be otherwise here?

The increase of this traffic, as shown by the statement, has been too strong to yield to the general depressions of 1857 and 1858, and promises for the future a large volume to draw from.

By the time the Tunnel can be completed, the public interest requiring it will have grown large enough to pay for the outlay.

The impulse given to business by the new facility would soon fill up the new line, and make up the temporary loss felt by any other.

Considering the large sum which the Commonwealth has already invested in this work, which must be sunk if it is not completed; the reasonable protection from loss which is offered by the other Companies interested in the line; the more intimate relations it may promote between Massachusetts and the West; and the benefits which such an additional facility promises to

the great interests of the city and State, we are of opinion that the work should be undertaken by the Commonwealth, and completed as early as it can be, with due regard to economy.

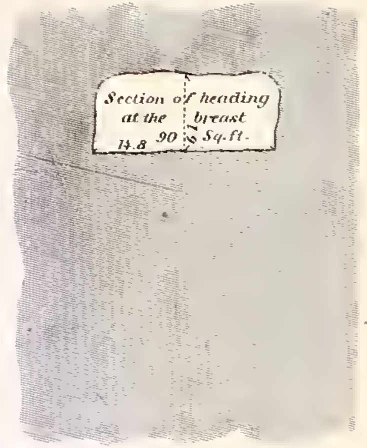
We have the honor to be,

Respectfully, your obd't servants,

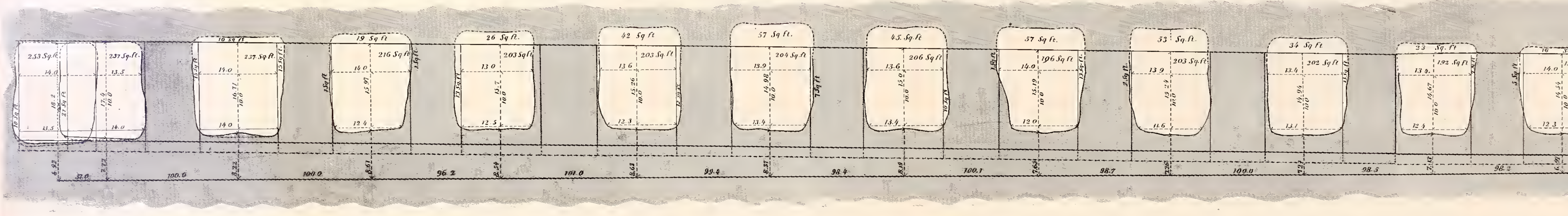
J. W. BROOKS,
S. M. FELTON, } *Commissioners.*
ALEX. HOLMES,

February 28, 1863.

Sections of so much of the proposed **HOOSAC TUNNEL** as has been worked at its E
These sections are so arranged as to show their variations from grade, and also by full ve
A grade of 0.35. in 100. equal to 18.48 feet per mile, has been drawn which very nearly agr
This line and another 18. feet above and parallel, are drawn in full line, while still another i
A level full line is also drawn from which the elevations are given.
The dotted vertical lines in each section represent the centre line, straight from end to end,
There are set in these sections, approximate areas showing the waste area at the top, and on
The length of bottoming is 2116 feet, inclination of breast 8 feet, and extreme length of heading



COMMISSIONERS REPORT Plate A.



at its Easterly end,
by full vertical lines on each, their variations from line.
nearly agrees with the excavation in the extreme section.
another in broken line is drawn 1.75 feet below, showing room for ballast and track.

d to end, and the full lines on each side are 7 feet distant from the centre line.
, and on either side, and also the remaining or useful area.
f heading 270 feet, giving a total penetration of 2394 feet.

Boston January 29th 1863

THOMAS DOANE & JOHN DOANE Jr.
CIVIL ENGINEERS & LAND SURVEYORS
OFFICES
No. 4 CORNHILL COURT, BOSTON.
(Entrance opp. Head of State Street)
No. 15 CITY SQUARE, CHARLESTOWN

Longitudinal Scale 50 feet to an inch.
Scale of Sections & vertical Scale of Profile 12 feet to an inch.

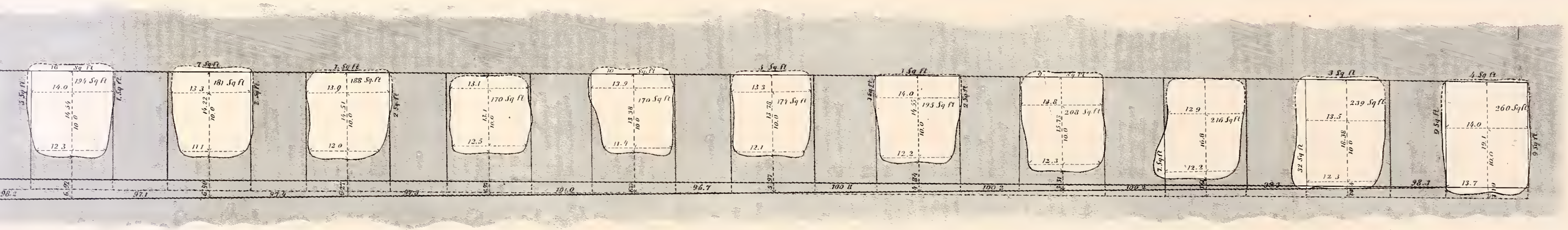


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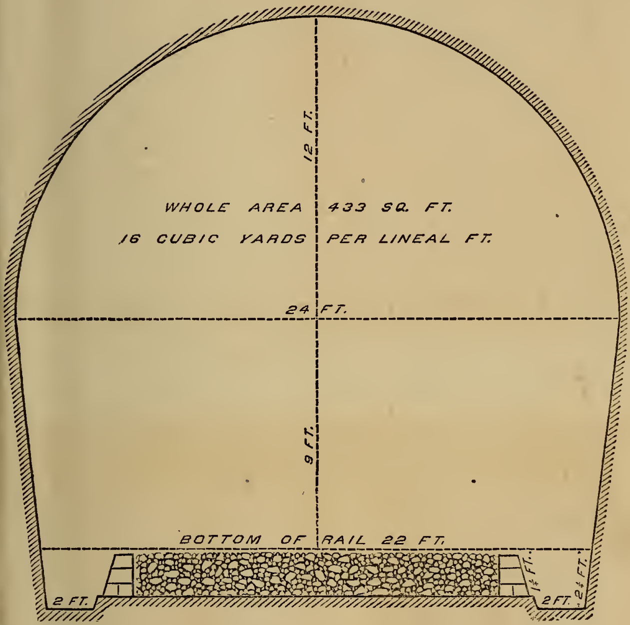
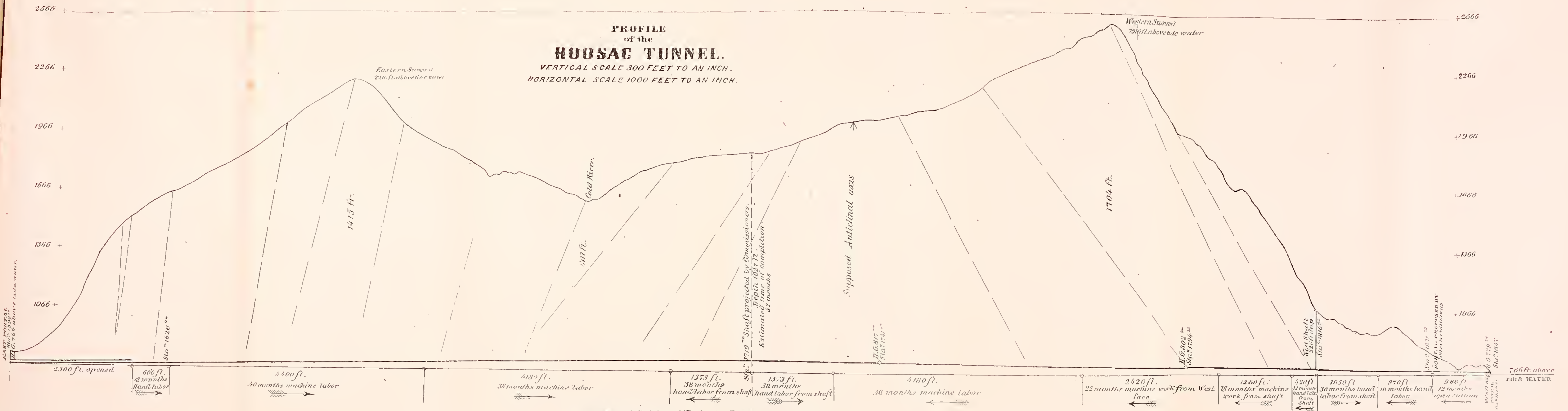
PLATE B.



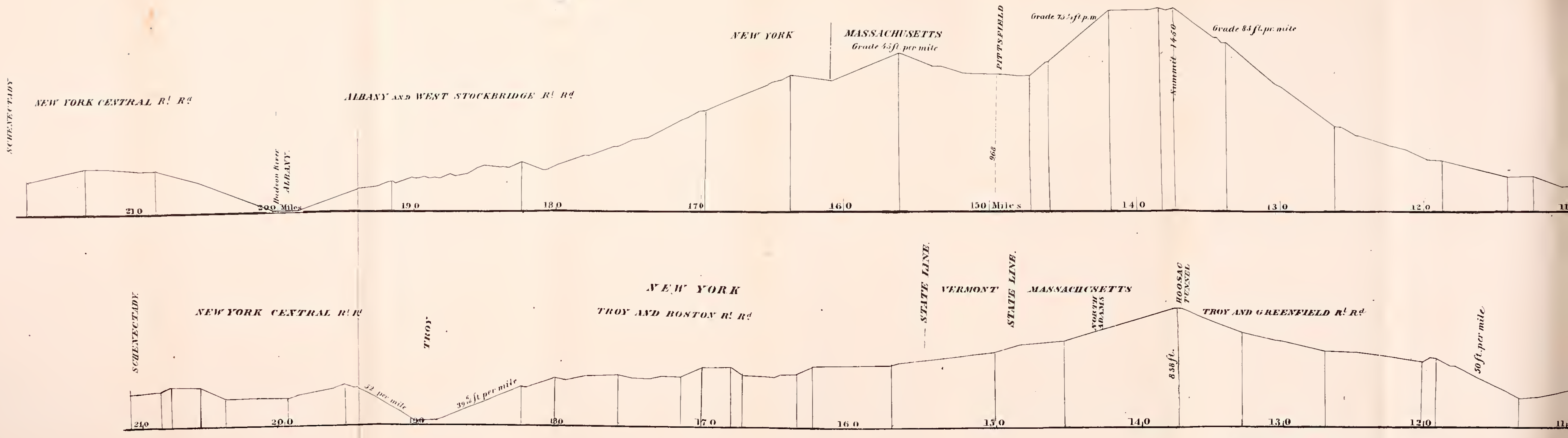
SECTION OF THE HOOSAC TUNNEL,

proposed by the Commissioners, with Side Drainage.

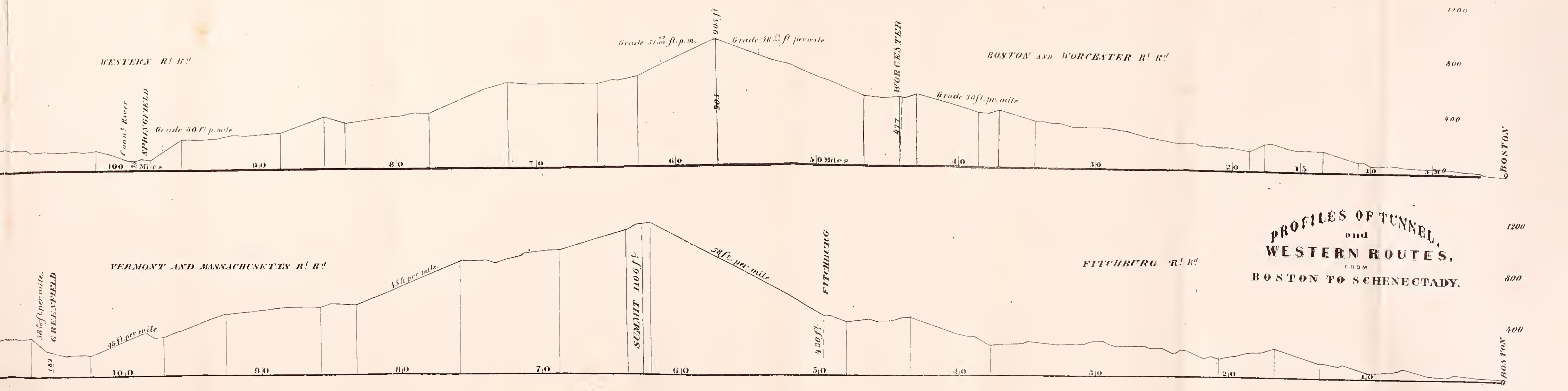


COMMISSIONERS REPORT Plate C.


VERMONT
MASSACHUSETTS
NEW YORK
SCHENECTADY
TROY
ALBANY.
HUDSON RIVER.
EAGLE FALLS
TROY & BOSTON R.R
CHATHAM CORNERS.
NORTH ADAMS
HOOSAC TUNNEL
Pittsfield & N.Adams R.R.
PITTSFIELD
Western R.R.
Troy & Greenfield R.R.
GREENFIELD
Conn. Rr. R.R.
Vermont & Mass R.R.
CHESHIRE R.R.
FITCHBURG
Fitchburg R.R.
WORCESTER
Boston & Worcester R.R.
Western R.R
SPRINGFIELD
BOSTON
COMMISSIONERS REPORT Plate D.
Sketch of TUNNEL and WESTERN ROUTES
from BOSTON to SCHENECTADY.
SCALE 5 MILES TO AN INCH.
FEB 17th 1863.



COMMISSIONERS REPORT Plate E.



PROFILES OF TUNNEL, and WESTERN ROUTES, FROM BOSTON TO SCHENECTADY.
WESTERN Rl. Rd.
BOSTON AND WORCESTER Rl. Rd.
VERMONT AND MASSACHUSETTS Rl. Rd.
FITCHBURG Rl. Rd.
Grade 60 ft. p. mile
Grade 30 ft. pr. mile
905 ft.
904
WORCESTER
477
SPRINGFIELD
Conn. River
BOSTON
GREENFIELD
182
48 ft. per mile
45 ft. per mile
58 ft. per mile
SUMMIT 1106 ft.
FITCHBURG
430 ft.
1200
800
400

APPENDIX.

REPORT OF CHARLES S. STORROW,

ON

EUROPEAN TUNNELS.

REPORT ON EUROPEAN TUNNELS.

BY CHARLES S. STORROW.

BOSTON, November 28, 1862.

To Messrs. J. W. BROOKS, S. M. FELTON, ALEXANDER HOLMES, *Commissioners appointed under the Act of the Legislature of the Commonwealth of Massachusetts, approved April* 28, 1862, *in relation to the Troy and Greenfield Railroad, and Hoosac Tunnel.*

GENTLEMEN, — Having at your request with the approval of the Governor and Council, undertaken a journey to Europe, for the purpose of examining some of the most important tunnels there constructed, and especially the one now in progress under the Alps, at Mont Cenis between France and Italy, which in many respects was supposed to be a work more nearly analogous to that proposed under the Hoosac mountain than any other, I left home on the 28th of July last and returned at the close of October and now have the honor to submit to you the result of such examinations as I was able to make during the period of time devoted to this object.

On my arrival in England, through the kind offices of Messrs. Baring Brothers & Co., and also of Mr. Thomas E. Blackwell a distinguished engineer, who has numerous friends in America, I readily obtained introductions to the members of the profession whom I particularly desired to see, and facilities were freely offered me for visiting the works under their charge.

The Great Western Railway, with its numerous branches, forms one of the most important lines in England. Some portions of it pass through a very rough country, where frequent tunnels are required, and the gauge of this road being seven feet, which is wider than that of any other in England, its tunnels have all been constructed of large dimensions and are fine specimens of workmanship.

This road, originally built by Mr. Brunel, is now with its branches under the charge of Mr. Michael Lane as engineer, a gentleman of very great practical experience, long associated with Mr. Brunel, under whom he was connected with the construction of many important and difficult works including the tunnel under the Thames at London.

In company with Mr. Lane I walked for a mile in the new tunnel, starting from the Paddington terminus of the Great Western Railway and running under London towards Newgate, being a part of the Metropolitan extensions, or lines intended to bring the various railways entering London into communication with each other. This tunnel—where I saw it—is near the surface and is in fact rather a railway track arched over, than a tunnel in the usual acceptation of that term. It is lined throughout with brick masonry, which appears to be extremely well built. Tunnels of this sort are not unfrequent in the large cities of England, where land is very valuable, and tracks can thus be made to cross important thoroughfares without hindrance. There is little to be learnt from them however, in relation to the work we have now more particularly in view in Massachusetts.

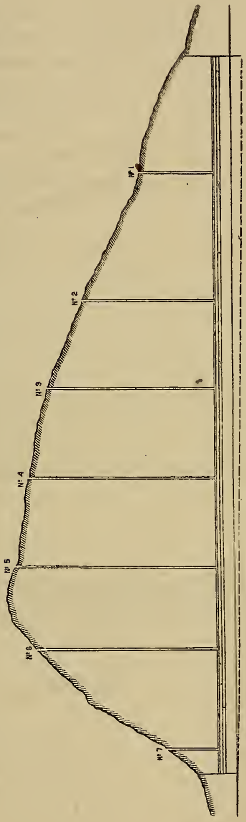
Mr. Lane kindly furnished me with letters to the resident engineers at various stations upon the Great Western Railway, with which I at once proceeded to Bath and Bristol.

BOX TUNNEL.

"The Box Tunnel," between Chippenham and Bath, is the most important tunnel upon the Great Western Railway. It is thirty-two hundred yards, or more than one and three-quarter miles in length. In section it is thirty feet wide at its greatest width, and about twenty-four and one-half feet high above the rails. Nearly one-half its length passes through Bath oolite, of which I have brought home specimens; the other half through clay. The accompanying drawing, given me by Mr. Lane, shows more particularly its transverse section; and the profile, which I copied from a drawing in the office of Mr. Reynolds the resident engineer at Bath, shows its grade and the position of the shafts. [PLATES I., II.]

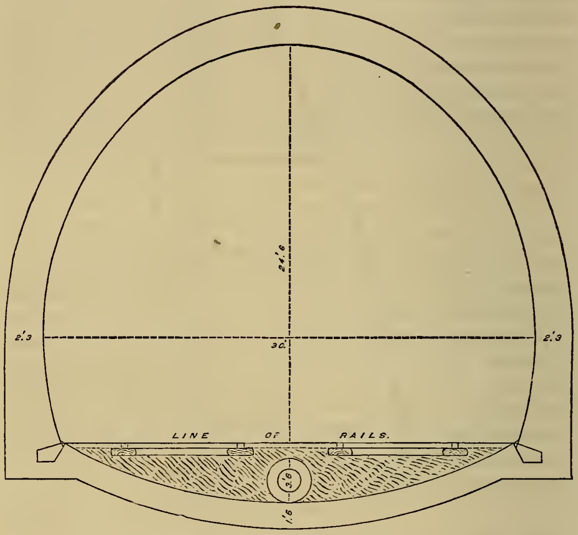
It is straight, and rises from one end to the other at the rate of 1 in 100, or $52\frac{8}{10}$ feet per mile. For about three-quarters of a mile from its upper or eastern end, it is a rough cut in rock, with no lining of masonry, except that here and there small pieces of brick work are built in, to secure weak spots—looking like mosaic upon the natural face of the rock. The remainder of its length is lined throughout with masonry, the sides being in general built with Bath oolite, excavated during its construction, and the arches of brick. The thickness of the lining is twenty-seven inches, except at the invert, where it is eighteen inches only. There is a drain in the

PLATE I.



PROFILE OF BOX TUNNEL.

PLATE II.



SECTION OF BOX TUNNEL.

centre, which Mr. Reynolds told me was two feet wide by two and a half feet high, covered and out of sight, as is usual in England. The sketch given me by Mr. Lane shows a different form of drain; but I may here remark, that in works of this character, which have been built for more than twenty years, and have therefore necessarily undergone repairs from time to time, changes have sometimes been introduced, or slight modifications, either in drainage, or in masonry lining, and even to a slight extent in the internal dimensions of the tunnel, leading to some slight discrepancies in the accounts given by different persons of the same work.

The material of the road bed is gravel, and the rails here, as on other parts of this railway, rest on longitudinal timbers. Mr. Lane informed me that these timbers, which are pine from North America, last better in the tunnel where they are wet, than on other parts of the road where they are more exposed to changes of temperature. This was confirmed by Mr. Reynolds and by the inspector of the road having charge of the repairs, both of whom accompanied me in the tunnel. The profile shows seven shafts; five only are now open, the others having been closed after the construction of the tunnel. They are of unusually large dimensions, being twenty-five feet in internal diameter. They are over the centre of the tunnel, and where they intersect it, they are widened to the full width of thirty feet. The deepest of these shafts is about three hundred feet; they are lined with brick and the interior is smooth. Their great diameter seems to have been a peculiar notion of Mr. Brunel. The general opinion at present—in which I think the engineers connected with this line concur—is that such large dimensions are quite unnecessary,—and from nine to twelve feet in the clear is the size usually adopted upon more recent works. This tunnel was among the earliest railway tunnels in England, having been commenced in 1836 and completed in 1841.

In order to judge by personal observation of the ventilation in this tunnel, I first rode through it several times in passenger trains at the usual speed. In one instance, being alone in a compartment of the car, I opened all the windows and placed myself exactly where the smoke or steam would blow directly against my face. In no instance was I at all incommoded, and but for the difference of sound and light, I should not have noticed that I was passing through a tunnel at all.

Upon the visit which I made for the purpose of a closer examination, I walked about half way through it in company with Mr. Reynolds and the Inspector and slowly passed through the remainder in a hand car. On entering the tunnel the further end was very distinctly

2

seen; the day was clear and bright. After we had gone through about one-third of its length, a locomotive passed us, going down the tunnel, and produced no perceptible smoke. A moment after, an express passenger train passed us, going up on the other track. It filled the tunnel with smoke and produced perfect darkness—not only so that neither end of the tunnel could any longer be seen, but that upon removing the lights we were carrying, the person who sat at my side, talking with me and touching me, was absolutely invisible; with all this however, there was nothing in the least troublesome to respiration. As we proceeded and successively passed the large shafts, a ray of light appeared directly under them, which a moment after was lost again in the intense darkness and this continued until we reached the other end of the tunnel, after an interval of fifteen or twenty minutes from the passage of the express train. The tunnel is somewhat wet, but not so as to occasion much inconvenience except in a few spots, and at the shafts. At these a considerable quantity of water is constantly dripping down, which much annoys the workmen and all who have charge of the repairs. The ventilation of the tunnel depends a good deal upon the weather. Whenever a strong clear wind is blowing, the smoke escapes very quickly; but in foggy weather it is quite troublesome to the workmen. I could not find however, that it seriously interfered with their work; and indeed Mr. Amor, the inspector, told me there never was a time when work could not be done there if required. No artificial means have ever been used to ventilate this tunnel since it was opened for travel; but the passage of quick trains going down the tunnel, in the ordinary course of the operations of the road, is a powerful agent for this purpose. The grade, as has been stated, is 1 in 100, or 52.80 per mile. With so steep a grade, the steam, on the descent of the tunnel, is nearly or quite shut off and the train passes quickly through. The first engine which passed us, moving down, while we were in the tunnel, produced no perceptible effect upon the air; but in ascending the tunnel there is a great expenditure of steam; the trains move slowly and heavy trains are assisted by a second engine. All this of course vitiates the air, as we noticed upon the passage of the express train upwards. The quick passage of a train always produces a current in the direction of its motion, and if made by a train running downward and therefore using but little steam, its effect in clearing the tunnel is very marked. This effect however, is said to be rather impeded than assisted by the presence of shafts; and I found that the persons who had charge of this tunnel taking this circumstance into consideration together with the trouble

from water admitted by the shafts, would be pleased to have them closed altogether and to depend for ventilation upon a natural current from end to end, caused by difference of temperature, or prevailing winds, and the artificial current produced by the passage of quick trains. Thirty-four passenger trains and fourteen freight trains pass through this tunnel every day, making forty-eight trains one way in all. In addition to this there are frequent special trains and also the return trips of the assistant engines.

Where this tunnel is not lined with masonry a careful examination is frequently made by the workmen, with a ladder and torch, to see if any portions of the work have become loose or are likely to fall. If so, they are removed at once, and if the adjoining rock is hard, nothing more is necessary; otherwise, a lining of brick work is put in. The most dangerous enemy is frost. In winter enormous icicles are sometimes formed by gradual accretion and if not removed would be very dangerous. During the construction of this tunnel, great difficulties were encountered from the excessive quantity of water, which inundated the works, sometimes even occasioning their partial suspension and powerful means were required to overcome the obstacle. At one time the water fairly got the mastery over the machinery used for its removal, and it was only after starting an additional set of pumps, worked by a fifty horse-power engine, that the work could be resumed. I found it impossible to obtain any correct account of the cost of this tunnel. It was one of the early works of this kind and unquestionably a very expensive one; but it was part only of a very great and costly enterprise and I was frankly told that if I obtained prices, they could not be depended upon,—that in these great works many things were massed together, and that when a division was to be made between the several items, large sums might reasonably enough be thrown from one to another, to rest where they could best be borne. Indeed, any engineer who has had charge of very large works knows how difficult it is to keep the division of the expenditures correctly; and, in a case like this, where those who constructed the tunnel twenty-five years ago are no longer living, and those who now own it no longer care, it is out of the question to obtain reliable information. The general belief of those most likely to be correct was, that it must have cost at least £350,000,* or $1,750,000, which is about

* In reducing English and French money to our own, I take five dollars as the equivalent of one pound sterling, and one dollar as the equivalent of five francs. This is convenient for calculation, and sufficiently accurate for the comparisons which may be suggested in this Report.

$547 per yard in length. Many persons estimate it to have cost much more. Its cost however, is of but little consequence to us for our present purpose. The most interesting questions are its size construction and ventilation, which are easily obtainable.

Directly beyond the Box Tunnel on the way to Bath is the

MIDDLE HILL TUNNEL.

This tunnel is short, only six hundred and fifty feet in length. It is similar to the Box Tunnel in section, and is lined with masonry the whole way. Beyond this, and on the same line of railway, are the

TWERTON AND SALTFORD TUNNELS.

They are both short — the Twerton being about four hundred and forty yards in length, and the Saltford about two hundred and twenty. Their section is like that of the Box Tunnel already described. The Twerton Tunnel is in the blue lias and is lined with masonry throughout. It was constructed by means of three temporary working shafts, besides the two ends, and the line of rails is about seventy-five feet below the surface. Specimens of the blue lias I have brought with me. The Saltford Tunnel is in blue lias and is lined with masonry, but without invert, and is only about fifty-two feet below the surface.

These tunnels, which I passed through in a hand-car, on the way to Bristol, have no remarkable characteristics, but are mentioned to show at what shallow depths English tunnels are sometimes constructed, and for what short lengths the engineers in that country resort to the use of working shafts.

BRISLINGTON TUNNELS.

Near Bristol, on the same line, are three tunnels called the Brislington Tunnels, Nos. 1, 2, and 3, which I visited also in company with Mr. Reynolds, in whose division of the road they were situated. In section they are similar to the Box Tunnel, but not quite so high.

No. 1 is	330	yards	in	length;	
No. 2 is	220	"	"	"	
No. 3 is	1,100	"	"	"	

These tunnels are chiefly in Pennant rock, which is very much harder than the Bath oolite.

No. 3, which is the most important one, is left partly as originally cut in the rock, without any masonry,—is partly lined with masonry of Pennant stone, put in when it was first constructed, and partly lined with brick masonry put in after the line was opened for use. The Pennant is very hard, as will be seen by the specimen I have brought with me, and is said to be very durable. This is by no means the case with the Bath oolite, which I saw in repeated instances, both in and out of the tunnels in this neighborhood, to be crumbling and falling off in flakes from the face of the masonry where it is used. Indeed, at Bath the viaducts of the railway are in some places fairly mottled with brickwork, inserted to replace defective stone which required removal. The masonry originally put into the Brislington tunnels is extremely good; but wherever it has been found necessary to introduce masonry after the opening of the line, in consequence of the rock becoming loosened by frost or otherwise, bricks have been used as being more easily obtained and handled, and more quickly laid. Indeed, the use of bricks as a lining for tunnels appears to be very general throughout England and probably for these reasons. The drain in these Brislington tunnels is in the centre, between the tracks and covered, as in the Box Tunnel. In several instances where water from behind the masonry was troublesome, percolating from the top or sides after its construction, small channels about nine inches square were cut into the masonry, extending upwards vertically from the floor of the tunnel to the spring, or even to the crown of the arch, and then cut through it to the back side. The face was then closed up by one thickness of brick, leaving thus an internal flue or conductor to lead the water from behind the masonry to where it could reach the central drain. This was said to have been done in many cases with excellent effect. A similar brick flue was occasionally made against the face of the rock to carry to one side the drippings from a seam, which would otherwise have fallen upon the track. The cuttings on each side of these tunnels were quite deep, varying from fifty to seventy feet. The road-bed is of gravel—Mr. Reynolds remarking that he found it much the best material and adding that the timbers lasted longer in the tunnels where the gravel was wet than they did outside. There is no difficulty in these short tunnels as to ventilation.

From a manuscript paper read at a meeting of the members of the Institution of Civil Engineers in 1842, by Mr. Charles Nixon, who superintended a portion of the works between Bristol and Bath, I obtained the following information: — When the construction of No. 3

tunnel was commenced, it was supposed that three working shafts would be sufficient and the contract was made with this stipulation; but owing to the hard nature of the material and the limited time, it became necessary to make for this tunnel six additional shafts, making a total of nine—the object being to expedite the construction. The three working shafts were about one hundred and ten feet in depth and fifteen feet internal diameter; a driftway, seven feet wide and eight feet high, was run the whole length of the tunnel before the enlarging to its full section was commenced. This driftway was completed in eight months after the commencement of the work. The heavy cutting at the extreme ends not having been completed in season to allow the tunnel excavations to be made from the entrances, the whole was excavated from the inside. The tunnel was worked at all nine of the shafts, but the materials only hauled up the three large ones. Ventilation was furnished to the workmen in the driftway by means of an air-tight tube and a fan revolving outside of the tunnel. The cost of the driftway, seven feet by eight, was ten guineas per yard lineal. As soon as it was completed a temporary railway for wagons was laid down. Here we have an instance of nine shafts in a length of eleven hundred yards of tunnel; and also may note the circumstance, that none of the work was done from the ends.

SAPPERTON TUNNEL.

The tunnel next visited was the Sapperton Tunnel, upon the Gloucester branch of the Great Western Railway, between Swindon and Gloucester. I had heard of it as one particularly troublesome in regard to ventilation, which therefore was a special subject of inquiry. Mr. Franks the resident engineer at Gloucester accompanied me, and readily furnished any information as to its present condition.

This tunnel is in section about twenty-eight feet wide, and twenty feet high, corresponding in general with the Box and other tunnels upon the Great Western line, but a little smaller. The main tunnel is one mile in length, after which comes an open cut of about one hundred yards followed by another tunnel of one-quarter of a mile in length. It passes through the oolite. It is lined throughout with masonry, and there are recesses on both sides, forty feet apart, large enough for two or three men to take refuge there upon the passing of a train. It had originally a number of shafts and all have been closed except one. That one is planked across at its lower end, where it

coincides with the top of the arch, with the exception of a small hole or scuttle, four or five feet square, which is left open.

I walked through the whole length of the tunnel. It was in good condition, and but slightly wet.

The grade is very steep, being 1 in 70, or 75.43 feet to the mile. Hence, in running up the tunnel, a great deal of power is required, and an assistant locomotive—placed in front of a passenger train and in the rear of a freight train—is kept constantly in use. This of course creates a large additional development of steam and smoke, so that after the passage of a single heavy freight train up, the smoke would fill the tunnel for hours and be quite offensive. Formerly coke was required by law to be used upon the English railways, but of late years the law has been disregarded, and coal, which produces a much greater volume of smoke, is now almost universally used. All agree that this change has been very injurious to the air in the tunnels. At the Sapperton Tunnel, the assistant engine is usually run down the tunnel immediately after the train has passed up, and this assists in clearing away the smoke; but a quick passenger train, running down the steep incline at great speed, is found to be far more effectual, and is indeed the only effectual ventilator.

The inspector of the road, who accompanied us, thought the opening in the shaft was of some use and said the men wanted it. Mr. Franks thought it of no use whatever; that it was something of a nuisance from the water which dripped from it. I am inclined to believe that the opening is left to gratify the men, but that in its present condition, at least, it is useless for ventilation. Mr. Franks, indeed, thought that as a general thing it would be better, after a tunnel is constructed, to close all the shafts and trust to quick trains for ventilation, because if left open, they cause eddies, like openings in the side of a chimney, admit water, need repairs, and offer no substantial advantage to counterbalance these evils. As the tunnel now is, I was told that the men work all day in it whenever necessary, although they do not like it; but that if two freight trains should follow each other up without the smoke being cleared away, it would be very difficult for them to work, and if four trains followed each other, it would be impossible.

I confess myself unable to account satisfactorily for the bad ventilation of this tunnel. Its section is large, its length not excessive—none of those who have the care of it think of re-opening the shafts. On the contrary, they are inclined to close completely the last one. The difficulty may result partly from the very steep grade, and partly from some peculiar circumstances in its position or exposure. Looking at

the two tunnels together, as forming one tunnel, a mile and a quarter long, with an opening of one hundred yards one mile from one end and a quarter of a mile from the other, we should, *a priori*, have expected excellent ventilation.

We shall hereafter see an instance of a longer tunnel in Switzerland, with no shafts at all, in which there is no such difficulty as is here found.

I stood in the middle of the Sapperton Tunnel when a train passed *down* at the rate of about twelve miles an hour. It made very little smoke and left both ends of the tunnel distinctly visible.

I stood in one of the recesses, about a couple of hundred feet inside, when an express passenger train passed *up*. It filled the tunnel completely with smoke.

I stood a few yards outside of the tunnel, when a heavy coal train passed up and came out of it, with an additional engine pushing in the rear. The smoke and vapor were extremely thick, and as seen from the outside, the whole entrance of the tunnel was a black mass. Nor indeed did the return of the assistant engine down the tunnel seem to have any effect during the short time I afterwards remained there.

The day was bright and clear. When we walked through the tunnel before any train had passed, it was free and clear from smoke or smell, and one end was distinctly seen from the other.

WOODHEAD TUNNEL.

The Woodhead Tunnel, on the Manchester, Sheffield and Lincolnshire Railway, a short distance from Manchester, is one of the most remarkable tunnels in England. Mr. Sacré, the engineer of this line, sent his assistant, Mr. Lough, together with one of the road inspectors, the only person now connected with the road who remembered any thing about the original construction of the tunnel, to accompany me through it on foot, or in a hand car, and we spent a large part of a day in and about it.

The whole length of the tunnel is three miles, eight yards, two feet. Its section is peculiar. It was originally built for a single track only; fourteen feet and four inches wide at the level of the rails; eighteen feet three inches high from the rails to the under side of the arch; the sides vertical, with no invert, and a small drain next to the wall on each side of the track. This is almost exactly the present section of the Hoosac Tunnel. After a few years use, it was enlarged—

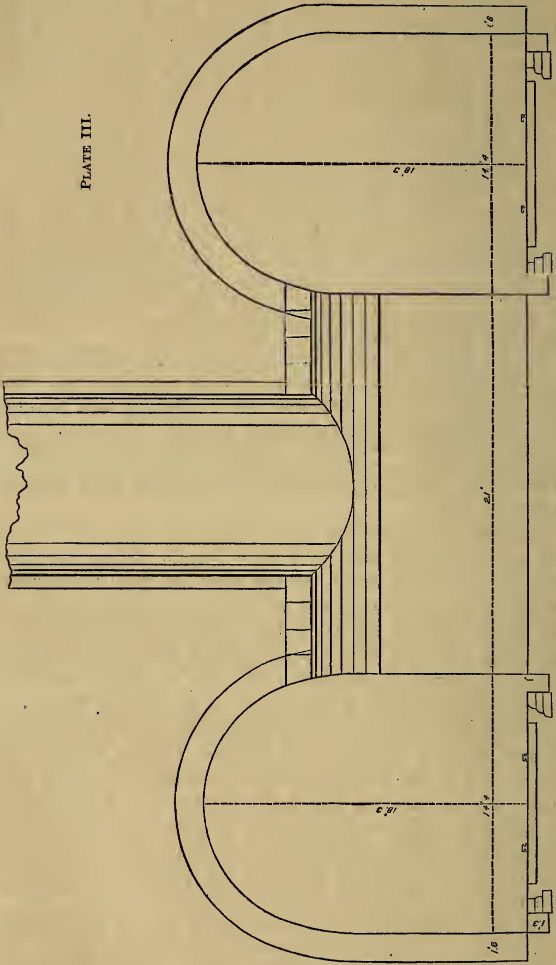
if such a term may be used—by the construction of a second tunnel of precisely the same dimensions, parallel with it throughout, and separated from it by a longitudinal pier, twenty-one feet in thickness. It is now therefore in fact a double tunnel, for a double track, the space between the two tracks being simply wide enough to admit the intervening pier. There are twenty-one arched openings, eleven or twelve feet wide, from one tunnel to the other. The first tunnel was built with shafts of about ten feet diameter, of which five are still open. These shafts were not central over the line of the tunnel, but entirely on one side; and the second tunnel being on the same side, the shafts are now directly over the pier, which separates the tunnels, and therefore central to the whole work. They now terminate at the roof of the arches, which run across from one tunnel to the other, and are thus freely in communication with both. The accompanying sketch will show this more clearly. [PLATE III.]

The line first built, or the *down* line as it is now called, was left in part without lining, where the natural rock was sufficiently firm. From my examination I should think about half a mile may have been thus left. The remainder is lined with stone masonry. The second tunnel is lined throughout. There is no invert on either line, except for a short distance where the ground was soft, and it was there necessary for both of them.

This tunnel is straight from end to end, and with one grade of 1 in 200, or 26.40 ft. to the mile, for its whole length. It has often been called the *summit level* tunnel, and this name has given rise to misapprehension, both in America and in England. I had been informed that, like the Hoosac Tunnel, it had a summit in its centre, and a descending grade from there towards each end, and of course felt great anxiety to examine its ventilation. But this is not the case. It is situated at the summit of the general rise of ground from Manchester towards Sheffield, and it is just after passing out of it that the grade of the road begins to descend. It is therefore simply a tunnel at the summit level of the whole line, which circumstance has given it its name. The first line was built as usual with shafts. In constructing the second, the shafts were not used at all; but the side walls being first cut through and openings made horizontally into the line of the new tunnel, all the material excavated was brought by traverses or cross tracks to the finished line and run out in cars.

The rock through which the tunnel passes is shale and millstone grit. The parts left without masonry are in millstone grit and I was told that there was less dripping of water there than through the

PLATE III.



WOODHEAD TUNNEL.—Section at a Shaft.

masonry elsewhere. The deepest shaft is more than six hundred feet —the least about three hundred. The hill is very abrupt in its rise. The cut at each end is very short, and appears to have been merely opened sufficiently to give a fair place for the masonry of the entrance.

Once a month the parts which are in rock excavation, without lining, are carefully examined, to see if there are any loose pieces.

The tunnel was used as a single line for six or seven years after its construction. It was worked entirely with a *pilot* engine ; that is, only one engine was allowed to draw trains through it; consequently there could be but one train in the tunnel at once, and a collision was impossible. The rule of never allowing a second train going in either direction to enter a tunnel until the first is entirely out of it, I found to be invariably adopted at every place which I visited. Telegraphic signals are generally interchanged between the guards at the two ends of long tunnels, denoting that a train has entered, or a train has passed out. Mr. Lough and his inspector both expressed a great preference for a double tunnel, instead of a single large tunnel for two tracks, especially because when repairs are needed, they can close one line and work the other with a pilot engine. There may be some convenience in this, but the opinion of English and other foreign engineers generally I believe to be quite the reverse.

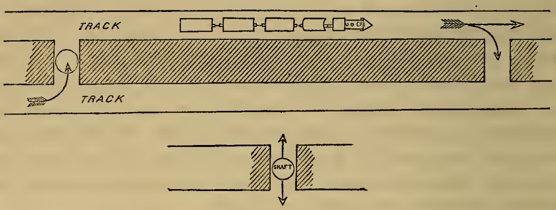
The road bed is ballast as it is on the adjoining parts of the line. Gravel is preferred, but ballast or broken stone is used where it can not readily be obtained. No material difference had been noticed in the duration of the sleepers there and elsewhere. The two tracks are usually kept in repair by two foremen and five laborers. The men call it a bad place to work in; some have left it, thinking it made them sick. The general result seems to be that they do not like it, but continue to work there, and some of them have been steadily employed for six or seven years.

Twenty-eight regular trains in each direction besides special trains pass through the tunnel daily, making about sixty one way in a day.

The ventilation of the tunnel is said to be much better on some days than on others. The day of my visit was a clear bright day, rather cold. I was told that the tunnel that morning was in good condition as regards ventilation. While I was in it several trains passed in both directions ; one while I was standing in a recess next to the track on which it came ; one while I was on the other line ; one while I stood in the passage between the two. As the train approaches you feel the air driven forward, and also rushing through the openings into the other tunnel. The moment the train has passed it pours back again through

the openings from the other tunnel to follow the train. At the shafts the current was uniformly *down* and very strong, both at the time trains were in the tunnel and when they were not. A great deal of water was dripping from them all, amounting in some of them to a small stream. This fortunately did not fall upon the track, but in the arched chamber or opening between the tunnels where boards and masonry were arranged to receive it and carry it to the drains. This water which was quite cold may have contributed by its mechanical action, as well as by its temperature, to produce the downward current.

The adjoining sketch will show the general direction of the current in the tunnel.



The Inspector told me that this downward current at the shaft was frequent, but not invariable, and that he had often seen smoke issuing from the shafts above. All parties here thought the shafts very useful for ventilation.

While I was standing outside of the tunnel at its lower end some time after trains had passed, the smoke was pouring profusely out from both arches. A freight train approached and went up. Immediately after its entrance the smoke ceased to come out of the arch by which it had entered, and evidently the air was following the train. From the other arch the smoke continued to pour out as before.

The tunnels of which I have given some account in the preceding pages are completed tunnels, all of them constructed many years ago. They are the only completed ones which I examined with care and may serve as a sample of the English tunnels generally. There are many others which I passed through several times, simply to see if there was any inconvenience to passengers under any circumstances, but without stopping for a close examination. From finished tunnels there is but little to learn by inspection, except as regards their

section, length, shafts, ventilation, and the frequency or difficulty of repairs. The difficulties of construction and peculiar modes of overcoming them, which would be most interesting, have been forgotten, and the knowledge of these details seems to have disappeared with the persons who built them. Mr. Lane told me that there were no accounts in his possession from which such information could now be obtained for works upon the Great Western Railway, that all papers of that sort were formerly in the hands of Mr. Brunel, who is no longer living. The different works upon the London and Birmingham Railway, especially the Kilsby and Watford Tunnels, the first of which was said to have broken the backs of several contractors, and nearly broken the heart of George Stephenson, were constructed by that eminent engineer, who has also passed away. Mr. Locke who built the Woodhead Tunnel, is no longer living and several others since connected with that line and from whom I hoped to obtain further details are also dead. I endeavored to obtain from Mr. Sacré any papers or memoranda or estimates or accounts of cost, and was informed that they had unfortunately been destroyed by fire. These things are mentioned simply as showing the difficulty of obtaining precise and reliable information in regard to the details of these works.

Very little has been published in England upon the subject. Mr. Forrest, the secretary of the Institution of Civil Engineers in London, who kindly assisted me in my inquiries, ransacked the library of the Institution for me and took down every thing he thought would prove interesting, but the list was lamentably small and the accounts meagre. There is a work on "Practical Tunnelling," by F. W. Simms, of which a second edition was published in 1860, which was spoken of as the most complete English work of the kind. It gives full and careful descriptions of two important works, the Blechingly and Saltwood Tunnels, upon the London and Dover line, the construction of both of which was under the superintendence of the author as resident engineer. It contains not only an account of these works as finished, but gives full details of progress and cost, and methods of construction. As I have brought home the volume for the use of the Commissioners it is unnecessary that I should give them extracts therefrom. I endeavored to find Mr. Simms hoping to hit upon a mine of valuable information, but learnt that he had died within a year or two. In Roscoe's London and Birmingham Railway, there is a short description of the Kilsby and Watford Tunnels, and as the work was published some twenty or more years ago and is perhaps not easily to be found, I add an extract from it which may perhaps be of interest to the Commis-

sioners. I passed many times through both these tunnels, and they, like most others, have long ceased to attract the attention of travellers in England where tunnels are now so common, more than eighty miles in aggregate length being already in use.

KILSBY TUNNEL.

"The Kilsby Tunnel is about 2,423 yards long, and was intended at first to be formed eighteen inches thick in the brick-work, but it was found necessary to increase this in most cases to twenty-seven inches. The whole has been built in either Roman or metalic cement.

"The works were commenced in June 1835 by the contractors; but such serious difficulties were met with at an early stage of the proceedings that they gave up the contract in March 1836 and nearly the whole work has been performed by the company. Previous to the commencement of the works, trial shafts were sunk in several parts of the line of the tunnel, in order that the nature of the ground through which it would have to pass might be ascertained, and it was found to be generally lias shale with a few beds of rock—in some places dry, in others containing a considerable quantity of water.

"In sinking the second working shaft it was found that a bed of sand and gravel, containing a great quantity of water lay over part of the tunnel; and this was such a perfect quicksand that it was impossible to sink through it in the ordinary way. By repeated borings in various directions near this part of the tunnel the sand was discovered to be very extensive and to be in shape like a flat-bottomed basin, cropping out on one side of the hill. The trial shafts had accidentally been sunk on each side of this basin, so that it had entirely escaped notice until the sinking of the working shaft. Mr. Stephenson was led to suppose that the water might be pumped out and that under the sand thus drained the tunnel might be formed with comparative facility. This proved to be the case. Engines for pumping were erected and shafts sunk a little distance out of the line of the tunnel. The pumping was continued nearly nine months before the sand was sufficiently dry to admit of tunnelling and during a considerable portion of that time the water pumped out was two thousand gallons per minute. The quicksand extended over about four hundred and fifty yards of the length of the tunnel and its bottom dipped to about six feet below the arch.

"In May 1836, one of the large ventilating shafts was commenced and completed in about twelve months. This shaft is sixty feet in diameter and one hundred and thirty-two feet deep. The walls are perpendicular, and three feet thick throughout, the bricks being laid in Roman cement. The second ventilating shaft is not so deep by thirty feet. These immense shafts were all built from the top downwards by excavating for small portions of the wall at a time, from six to twelve feet in length and ten feet deep.

"In November 1836 a large quantity of water burst suddenly into the tunnel in a part were there where no pumps; it rose very rapidly, and in order to prevent the ground being loosened by it at the far end, where it was excavated, a rather novel mode of building the brick work was resorted to. This was by forming a large raft and on this the men and their materials were floated into the tunnel and with considerable difficulty and danger performed their task. All the difficulties were at last conquered, and the tunnel finished in October 1838, but of course the expenses were increased to a very great extent."

"The contract for making the Kilsby Tunnel was £99,000, and it has cost more than £300,000, or upwards of £130 per yard.

"The quantity of soil taken from the tunnel was 177,452 cubic yards. The great ventilating shafts are perfect master-pieces of brick-work and are found fully to answer the purpose for which they were intended, leaving the tunnel entirely free from any offensive vapor immediately after the transit of each train."

WATFORD TUNNEL.

"This tunnel is one mile and one-tenth in length and is excavated entirely from chalk and loose gravel, the treacherous nature of which rendered it a work of great difficulty. It was first formed by sinking six shafts to a certain depth, and then excavated horizontally in what is called by miners a 'drift.' An idea may be formed of the treacherous nature of this soil, when it is known that a certain part of the tunnel was found to consist of such firm and solid material that the invert which supports the upper structure of the brick arch and sides was not introduced, but that the side walls rest upon the chalk; yet other parts were so mixed with gravel and sand, that when in the course of the operation a fissure was made, a stream of it poured in like water.

"In passing through the tunnel and near the centre, travellers will not fail to observe a wide opening or shaft. This was formed through an unfortunate accident which occurred here during the formation of the tunnel. At this spot one of the six working shafts was sunk of about eight or nine feet diameter, and it had been nearly finished when the whole mass of soil surrounding it gave way, completely burying ten men who were at work below. They were engaged in fixing one of the iron rings which are built into the top of the tunnel, to support the brick-work of the shaft, and from all that could be learned from observation—for not one was spared to tell the tale—it appeared that one of the men had cut away some of the chalk to obtain more room to fix the iron-work, and in so doing had penetrated so near the gravel that it broke through in an instant and entirely filled up the space, leaving them not a moment's time to save themselves. So instantaneous was the accident, that one poor fellow was found three weeks afterwards, standing perfectly upright with his trowel in his hand. It was nearly a month before the soil that had given way around the shaft could be cleared out, when the opening was found to be so extensive that the idea of making a large ventilating shaft at once occurred, and it was immediately executed."

LINDAL TUNNEL.

This tunnel upon the Furness Railway is one which presents some features of great interest, from the fact that having been originally built of small section, it was afterwards enlarged sufficiently to receive a double track, without interrupting, except for a very few days, the traffic of the railway which passes through it. A description of this tunnel is printed in the minutes of Proceedings of the Institution of Civil Engineers, Vol. xix. Mr. Stileman, the engineer who executed the enlargement, and with whom I had the pleasure of an interview in London, kindly gave me the drawing which is annexed to this Report. It is a copy of that prepared by him for the paper above referred to, which he presented to the Institution.

The tunnel was originally intended to be of sufficient size for a double track, but financial difficulties led to the reduction of its section to 12 feet in width and 14 feet 6 inches in height. Its length was 563 yards—of which 176 yards were in solid rock and 387 yards in loose material lined with masonry. The grade through the tunnel is 1 in 100 or 52.80 feet per mile. When the rail-

way of which it forms part became united with a more important line, it was found indispensable to enlarge it for the wants of a more extensive traffic. Two plans were proposed. One to build a second tunnel parallel with the first as at Woodhead—the other to enlarge the original section to the requisite dimensions. The contractors offered and preferred to build the second tunnel rather than to make the enlargement at the same price. But such excessive difficulty had already been encountered from smoke and want of ventilation notwithstanding the shortness of the tunnel, that it was determined to enlarge it rather than to build a second.

The drawing annexed will give an idea of the manner in which the work was executed. [PLATE IV.]

During its progress the laborers sometimes found it utterly impossible to remain at their work, for the section being so small, the engines which took heavy trains up the steep grade completely filled the tunnel and headings with steam and sulphurous vapor, and made the air unfit for respiration. Mr. Stileman told me, that by far the best means of clearing the tunnel was to run a light engine with little or no steam rapidly through it.

In enlarging the tunnel it was also shortened from 563 to 460 yards in length, of which 123 are in solid limestone rock, and 337 in loose material, lined with masonry.

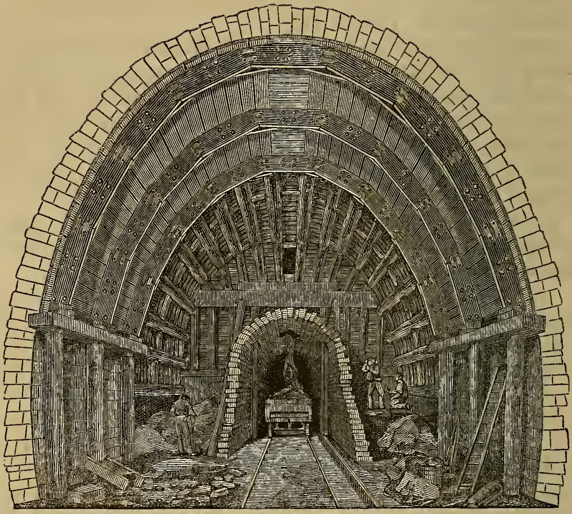
In 1849 the contract price for the small tunnel per lineal yard, in rock, was	$30 00
In 1854 the additional cost of enlarging, was . . .	106 00
Total cost per yard of enlarged tunnel in rock, . .	$136 00

In 1848 the contract price for the small tunnel lined with sandstone rubble masonry per lineal yard, was . .	$77 50
In 1854 the additional cost of enlarging was . . .	190 00
Total cost per running yard of enlarged tunnel in masonry,	$267 50

If the tunnel had originally been built for a double track as first contracted for, it would have cost,—

In rock per lineal yard, ...	$105 00
In masonry, ...	225 00

PLATE IV.



SECTION OF LINDAL TUNNEL.—Showing Method of Enlarging.

The time occupied in completing the 337 yards lined with masonry was sixteen months, and Mr. Stileman remarks in his paper that the whole time that the works were in construction was double the actual working time, so that it would appear that for work of this character it is necessary to allow the same time for contingencies as for the actual execution.

NETHERTON TUNNEL.

This is a tunnel for the passage of a branch of the Birmingham canal, and not for a railway. It is of quite recent construction having been completed in 1858 and is described minutely in the xix. volume of the proceedings of the Institution of Civil Engineers, from which the following details are extracted:

It is 3,036 yards or about a mile and three-quarters long, 27 feet wide, and 24 feet 4 inches high in the clear. The thickness of the brick-work, with which it is lined, is generally 1 foot 10½ inches in the walls and arch, and 1 foot 1½ inch in the invert, this thickness being however increased where the shafts join the arch, and also in some places where the ground was bad.

The lengths of the various sections of tunnel, as built, were as follows:

	ft.	in.		ft.	in.		yards.
Walls and arch,	1	10½	—Invert,	1	1½	—Length,	2,467
	1	10½		1	6		109
	1	10½		1	10½		85
	2	3		1	1½		375
Total length,	.	.	.	.	.		3,036

In several places where the foundation was "blue bind" or marl, the invert was forced up in the centre by the swelling of the ground. This was not accompanied by any subsidence of the side walls. And although the brick-work was in some parts raised five inches, it was not broken or crippled except at a point immediately south of shaft No. 7. Here the invert having been forced up eight inches in the centre and some of the bricks crushed almost to powder, it was cut out and rebuilt 1 foot 10 inches thick for a length of 130 feet. This was done in short pieces of about six feet at a time, the side walls being carefully strutted. In rebuilding a portion of this invert, 49 feet long, the versed sine was increased to 2 feet 6 inches.

For the construction of the tunnel 17 shafts were sunk, those positions being selected which offered the greatest facilities on the

surface for the deposit of the materials excavated. The distance between the shafts varied from 164 to 200 yards. Of the whole number, ten were merely intended for use during the construction of the tunnel, and seven were to be permanently left open for ventilation. The permanent shafts were all lined with brick-work nine inches thick. One which was worked with a horse gin was ten feet in diameter and the others were nine feet in diameter. The brick lining was supported, on the arch of the tunnel, by a cast-iron curb weighing nine tons, in four pieces strongly bolted together. Skew-backs were cast on the back of the curb to receive the rings of the arch.

The whole of the shafts were sunk by the ordinary method. The material having been removed to a depth varying according to the nature of the ground, an oak curb 9 inches by 3 inches in section was placed on the bottom on which the brick-work was built. The excavation of the length below was then proceeded with, the curb being temporarily propped, until underpinned by the brick-work brought up from the curb below.

The total depth of all the shafts was 3,083 feet, of which 2,293 were lined with brick-work. The greatest depth of any of the shafts was 344 feet 6 inches, and the least depth 65 feet 9 inches.

The average rate of progress per day of twenty-four hours from the commencement to the completion of each shaft, was 2 feet, but counting only the days on which the work was actually done it was 3 feet 4 inches. The ground was principally marl and "bind," but coal and basalt were met with in several of the shafts.

As soon as the sinking of any shaft was completed, the excavation of a bottom heading in each direction was immediately commenced and was proceeded with until it met that from the next shaft. The size of the heading was 5 feet by 3, the bottom of it being level with the top of the intended invert.

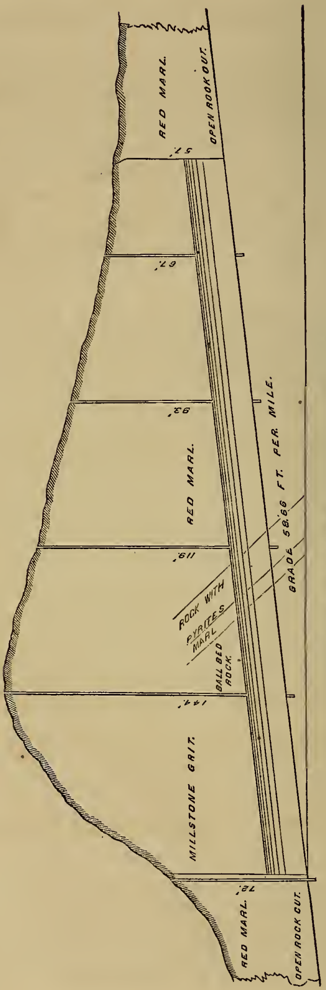
The time occupied in the construction of the tunnel itself from the commencement of the excavation at the foot of the first shaft to the laying of the last brick was almost exactly two years. This time seems exceedingly short for a tunnel of this length. Yet as the 17 shafts and two ends give 36 faces to work at, if all could be used at once, the progress would only be equivalent to about 3½ yards per month at one face. This however must have been very much less than the progress made at each face per month of actual work, because much time must have been spent in completing all the shafts, and therefore only a portion of them were probably in use at the same time.

ALMONDSBURY TUNNEL.

The field for lines of railway has already been so fully occupied in England that there is no very large amount of work of this kind in progress at the present time. I was therefore glad to find that a tunnel of importance called the Almondsbury tunnel, in the neighborhood of Bristol, on the Bristol and South Wales Junction line, was nearly but not quite completed and was therefore in a favorable condition for examination. My attention was directed to it by Mr. Lane of the Great Western Railway, who kindly furnished me with letters to Mr. Richardson, the chief engineer, and Mr. Rowland Brotherhood, the contractor.

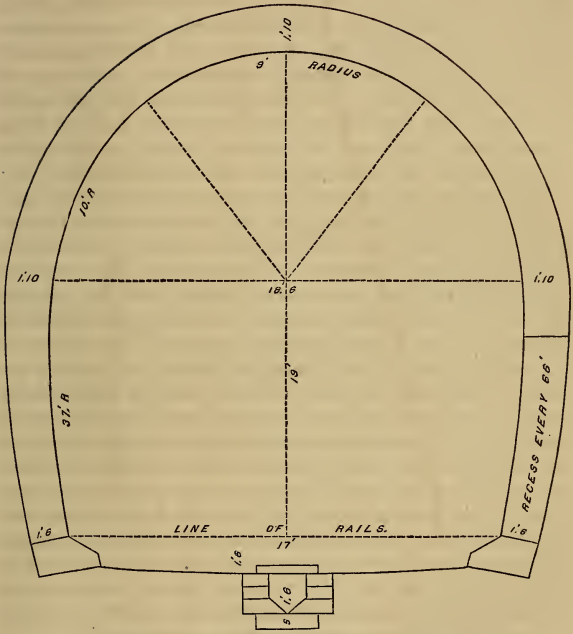
Mr. Richardson being absent at the time of my first visit, my information was mainly derived from Mr. Brotherhood, and from one of his sons who has been engaged upon the work, and also from the assistants in Mr. Richardson's office. This tunnel is about three-quarters of a mile in length, and is intended for a single track only. In section it is seventeen feet wide at the line of rails, eighteen feet six inches at the greatest width, and it is nineteen feet high above the rails. There are five shafts, the deepest of which is one hundred and forty-four feet and the least sixty-seven feet. The accompanying drawings, [Plates V. and VI.] exhibit the transverse section and profile more in detail. The section given was slightly deviated from, the tunnel being a few inches higher. There is no invert, and the drainage is under ground in the centre, the usual English plan. It will be seen by the drawing that shaft number five is precisely at the entrance of the tunnel, and that the cuts on both sides are very heavy. The whole work was done by means of the shafts. The tunnel has been virtually finished for many months, and is waiting for the completion of the excavations at the entrances. Owing to the delay in that part of the work, and the cessation of pumping operations, the tunnel has for a long period been full of water, and now that the excavations are approaching completion it is draining out. There is still so much water in it that I could not pass through it, but could enter for a certain distance only at the end where the principal rock cut is now in progress, and where the bottom had been left in parts higher than the rest. It is very evident that in England the engineers and contractors are not afraid of shafts, and depend much more upon them than upon the end faces for the prosecution of the work, there being frequent instances of tunnels finished entirely from the shafts before the completion of the

Plate V.



PROFILE OF ALMONDSBURY TUNNEL.

PLATE VI.



SECTION OF ALMONDSBURY TUNNEL.

cuts at the ends. The tunnel is straight from end to end, with a grade of 1 in 90 or 58.66 feet per mile.

It passes for about half its length—the upper half—through red marl, and the cut at that end is in the same material. The lower half is in rock, mainly mill-stone grit, excessively hard. Indeed it was spoken of as one of the hardest rock excavations in England. The deep cut at that end is of the same material and has proved very difficult and expensive. In addition to the mill-stone grit the cut at the lower end passes through mountain limestone. This is not so hard nearly as the other rock. The red marl is hard to work and seems like rock at first, but after exposure it crumbles away. Some parts of the tunnel are not lined. The stone where left to form the arch is very rough, which was said to be in consequence of its not being homogeneous; so that when left tolerably smooth, the softer parts become detached and leave the harder with a ragged surface. Mr. Brotherhood told me that the shafts were only intended for working, and they would all be filled up. The fifth being at the mouth of the tunnel, the five shafts gave only nine faces for work, and the tunnel is sometimes spoken of as having four and not five shafts. The tunnel was completed, or completed so far as was expedient until the end cuts could be taken out, in eighteen months. From each shaft, headings or drift-ways were run forward, about five feet square. Two miners and two strikers worked in each heading, besides men to carry out the material. This removal was done in small "skips" or boxes running on trucks, upon a railway track about two feet six inches in width. Including workmen employed upon enlarging the section, about thirty men worked at a face. The shafts were simply timbered at the sides, as wood is sufficiently durable for their temporary use for construction. Shafts are not, unless by special agreement, considered as permanent parts of the tunnel, but as implements of construction, at the charge of the contractor. So that when a contract is made for tunnel work at so much per running yard, which is the usual mode of contracting, the shafts are not paid for separately, but a stipulation is made for a certain number in order to ensure completion within a certain time.

In this tunnel there are beds of sandstone which are called *ball beds*, because they contain very curious balls or nodules of sandstone, distinct from the bed in which they lie, nearly spherical in shape, and from a few inches up to two and a half feet in diameter. They are not perfect in form, but look like a sphere from which about one-third had been split off.

I have brought with me specimens of the mill-stone grit, that its hardness may be compared with that of our rock at the Hoosac.

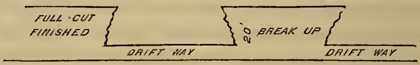
The length of the tunnel is 1,221 yards. If 1,200 yards required eighteen months, with nine faces, it would give a progress of about seven and a half yards per month at one face. As this includes, however, the time requisite for sinking the shafts, the progress must have been more rapid. From minutes furnished me in the office I obtained the following account: In March 1859, all the shafts had been started and one nearly completed. On the 30th July 1859, the shafts were all completed, a portion of the tunnel bricked in from each arch, and an aggregate length of 204 yards of tunnel completed. On the 7th January 1860, there were 685 yards, or more than one-half the tunnel, completed. This appears to have been a period of steady work, and the progress was 481 yards in five and a quarter months, which, with nine faces, would give a progress of very nearly ten yards per month at one face.

The contract price for work was stated to be £28 or $140 per lineal yard of tunnel complete, ready to receive the gravel or ballast for road bed. The amount of the whole contract taken by Mr. Brotherhood was £200,000, which included many miles of road besides the tunnel.

Mr. Brotherhood is not only a contractor of high character and standing, able to undertake and carry through works of great magnitude and cost, but also the owner of a very extensive machine shop and forge works at Chippenham, for the manufacture of locomotives and rolling stock generally, for steam-ship work, and for wrought iron girder bridges, many of which he has sent to Canada and to other parts of the world. He originally worked under Mr. Brunel, and after the completion of the Great Western Railway he took contracts for the maintenance of way on that line, which were renewed or continued for nineteen years. This of course has made him familiar with the use and repair of railways and tunnels, as well as with their construction, and I availed myself of the opportunity to converse with him at some length about the Hoosac Tunnel, of which I showed him the profile, and a specimen of the rock through which it passes, and explained to him the general characteristics as thus far exhibited by the progress of the work at the two ends and the western shaft.

He thought the rock he had encountered at Almondsbury was a harder and more difficult rock than ours. Good sound rock, if not extraordinarily hard, is good material to tunnel through, as you can dispense with timbering and with masonry, and are free from the treacherous character and unforeseen dangers of loose soil. In all cases it is better to run forward a heading in advance, and he prefers to make it at the *bottom* of the tunnel where the little wagons may

run, following on, as rapidly as possible, with the enlargement. The greatest cause of delay is the difficulty of moving the wagons. If the heading can be driven forward much in advance of the rest, while one party of workmen are completing the full cut other parties can "break up" the material over the heading in several places, making more faces, upon which an additional force can be employed.



and the number of "break ups" will be limited only by the difficulty of removing the materials through the drift-way. As soon as these spaces are somewhat enlarged and cleared the work progresses rapidly, for they make standing room for men, and room for the deposit of materials until the wagons can pass to run them out.

Hand labor for drilling is all he has ever used or would recommend. He knows of no machinery for the purpose ever having been used in England. It naturally occurred to me when going over his fine shop, filled with tools for a great variety of work, and managed apparently with great skill, that he was the very man to make his own machinery and to use it in the execution of his own contracts for tunnel work, if he thought there was any thing to be gained by it.

The grade of our tunnel, rising towards the centre and thereby facilitating the removing of materials and drainage of water at the two ends, seemed to him a favorable feature. The great trouble in the English tunnels, which are on one grade from end to end, is that the drainage can only be run out at one face, and from all the others has to be raised through the shafts. These shafts are considered necessary for working purposes, to facilitate construction, and most of them are generally closed after the tunnel is completed. In his opinion they are of no value for subsequent ventilation unless in a case of extreme length, and he would have them all closed. The true ventilator is a swift train passing through the tunnel, and shafts rather interfere with that, and with the natural current which sometimes sets through.

In the case of the Hoosac however he says unhesitatingly that there should be a shaft in the centre at the summit, and from its position and height he anticipates a great upward draft in it, independently of artificial means. Of course it would be expensive, and if there is much water would require very heavy pumping, but its aid in constructing and in ventilating the tunnel is of the greatest consequence.

In our tunnel he thought there would be a good deal of difficulty in supplying air to the workmen. Of the eventual ventilation, after completion, he had no fears, but apprehended that the trouble of furnishing air to the workmen would delay the work considerably. If after a blast, time is lost in waiting for the air to be pure enough to resume the work, it greatly impedes the rapidity of its progress. The greater the length and depth, the greater probably would be the heat and oppressive character of the air.

Speaking of the Box Tunnel of which he had the care for a long time, he said the ventilation would be better in his opinion if the shafts were closed. He found it troublesome to keep the road-bed in order, it being always wet, and the tunnel very dark. The pine sills last better however in the wet road-bed than they do elsewhere.

The earth work on his contract upon the Bristol and South Wales Junction line is very variable. Some of it has cost him 9*d.* or 18 cents per yard. Some as much as 2*s.* 6*d.* or 60 cents. The rock is excessively hard and in some places in the open cut would cost seven or 8*s.* or $2 per cubic yard.

I may here remark that the term "rock cutting" appeared to me less definite, and the line between "rock" and "earth" much less distinct in England than with us. A vast deal of the work which I saw there was in limestone rock, where there was every grade of hardness, some of it almost crumbling of itself, some of a harder character, but not too hard to be cut by the saw, and some, like the mill-stone grit, very hard. In our granite country the rock cutting with which I I have been acquainted is much harder than that of England generally.

Mr. Brotherhood said there were places where single track tunnels could be built for £20 or $100 per lineal yard. From that the price would range according to circumstances up to £45 or $225 per lineal yard.

He thought a long tunnel like the Hoosac quite uncertain work, especially because we could not foresee what difficulties we might encounter from water. Yet he had no question that it could be built, no doubt that the central shaft would furnish sufficient ventilation when completed, and wished it were not too far off for him to look at with a view to a contract.

In speaking of the deep shaft proposed at the Hoosac, he said that of course the expense increased with the depth, but that the great and uncertain element in the cost was the water you might encounter, and that this would render any estimate a very uncertain one.

On a subsequent visit to the Almondsbury Tunnel I had the pleasure of an interview, much shorter than I wished, with Mr. Charles Richardson the Chief Engineer of the Bristol and South Wales Junction line, of which it forms part. He is an engineer of distinction, an old pupil of Mr. Brunel and has had extensive experience both in tunnels and other important works.

As I had previously spent a good deal of time upon inquiries in relation to his tunnel, I now conversed with him more particularly about the Hoosac. He thought our mica slate which I showed him by no means a bad rock to tunnel through, and that our work, of which I gave him a description, was perfectly feasible, the question being only one of time and expense.

Our section as now adopted for one track he considered as decidedly too small. He knew of none so small, and would never advise its adoption. The grade of the road, with a summit in the centre, struck him unfavorably, because if you make a central shaft for purposes of construction, the water will follow you as you proceed both ways, and would naturally be deepest precisely where you are at work. Constant pumping would be required to keep not only the shaft but both faces clear.

In ordinary tunnels shafts are of but little use for ventilation, and he should depend more upon the natural current of air, and that produced by the passage of trains. In our case, however, a central shaft for ventilation would be indispensable.

In excavating shafts in England they usually begin to raise the materials by a windlass and men. Next comes the horse-gin, and finally the steam-engine. In making a shaft where a large quantity of materials is to be lifted and spread, the top of the shaft is usually brought up to some height above the ground in order to dispose of the materials raised, otherwise they must be removed some distance that they may not bury the mouth of the shaft. Local circumstances would indicate what is best to be done. It might in our case be advantageous not to make our shaft in the lowest part of the depression between the two summits, but a little way higher up, for disposing of the materials.

It is quite impossible to judge from the expense of sinking a shaft three hundred feet what would be the expense of sinking one eight hundred, because of the great uncertainty as to the character of the material, and the quantity of water that may be met with. The same difficulty applies to an estimate for our whole tunnel, which is different from any one constructed in England. It is impossible to foretell the character of the work on so long a line.

With regard to the means of furnishing ventilation to the workmen, which of course would be necessary during the construction of our tunnel, his experience led him to prefer to exhaust air from within, letting the fresh air from the entrance follow to supply its place, rather than to force air into the tunnel. In the latter case all the leaks are from within the pipe by which you convey it, and are difficult to stop. In the other case the leaks are inwards, and can easily be stopped by a little clay on the outside.

No English tunnel has ever had artificial ventilation for so great a length as we should require. In mines very great distances are supplied with air, but at great expense.

Very great precautions must be taken on a line of the length of ours, worked from the ends, to insure the exact meeting of the two portions. On his tunnels, where shafts are used, he drops fine wires from the surface near the two sides of the shaft and ranges his line by them; but with very long suspension wires, even if the plummets are in water, they oscillate so slowly that it is very difficult to be sure they are at rest. It might be better to let them hang in some denser liquid.

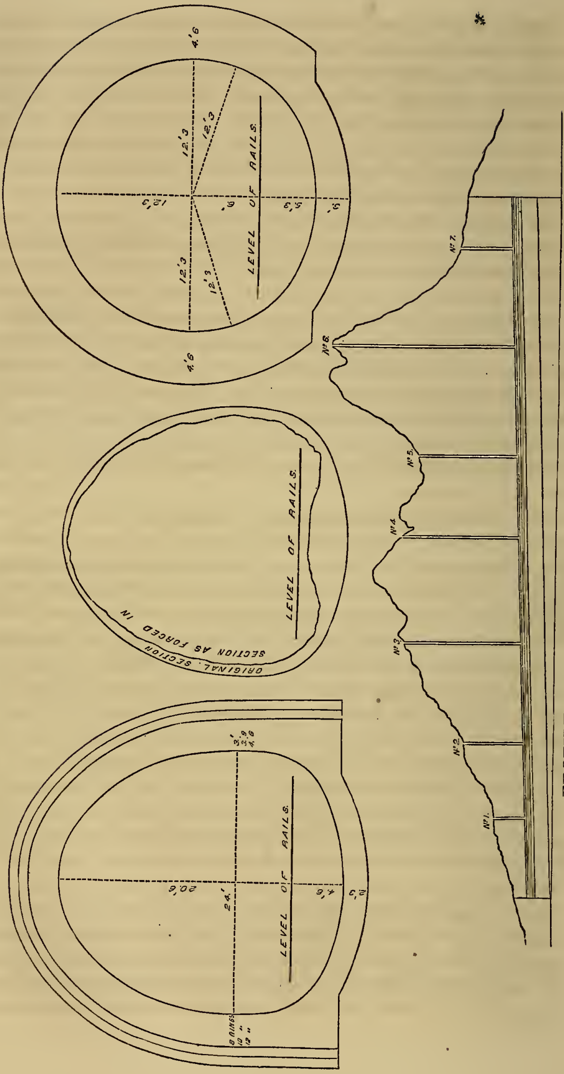
SYDENHAM TUNNEL.

A very interesting tunnel is now in course of construction at Sydenham, near London, on the London Chatham and Dover Railway, forming part of the Metropolitan Extensions.

It is entirely through London clay, and this material, which is excavated without much difficulty, requires of course no use of powder, and is quite free from water, yet has proved one of the most troublesome and expensive that could be encountered, far more so than any rock which I have seen in England. The tunnel is 2,100 yards in length. There are 7 shafts, all originally 9 feet in internal diameter, and varying in depth from 186 to 50 feet—as will be seen by the accompanying drawing, [Plate VII.] Two of them are to be left open permanently—the other five are to be closed upon the completion of the tunnel.

The peculiar characteristic of this clay is, that though removed without much difficulty, freely yielding to the pick and standing nearly vertical in the excavation, it subsequently swells and presses with such force against the masonry with which the tunnel is lined, as to deform or crush it and render necessary its removal and reconstruction.

PLATE VII.



PROFILE AND SECTIONS OF SYDENHAM TUNNEL.

Upon descending into the tunnel by shaft number three, in a skip or bucket raised and lowered by steam-power, I remarked the small size of the shaft, and was told by the inspector who accompanied me, that having been originally 9 feet in diameter, it was so pressed in by the surrounding earth that barely 6 feet was available for passage. A portion of the tunnel on each side of the shaft had been lined with brick and completed, but at the time of my visit was quite out of shape, and in places strengthened by heavy brick buttresses to sustain it temporarily. At the faces on both sides a large number of men were at work, the air was perfectly good and the tunnel dry. The mode of working forward, the propping up and timbering the roof and sides preparatory to the construction of the brick masonry, were precisely as described by Simms in his work upon tunnelling which I have already referred to. The skips, or little wagon bodies in which materials are removed, are placed on trucks, which run on double tracks of about $2\frac{1}{2}$ feet gauge, and 18 inches apart. The headings are about 4 feet by 6 in section, and are run forward at the *top* and not the bottom of the excavation.

Mr. James Baldwin, the engineer resident at the works, gave me the following particulars:

The swelling of the clay, crushing or thrusting in the masonry, had taken place to such an extent, that 6,780 cubic yards of side wall and 2,065 cubic yards of invert had been cut out and rebuilt in its proper position. The portion of the tunnel at the foot of shaft number three where I had seen it, which was the worst, was lined originally with 8 rings of bricks, making a thickness of 36 inches. It was necessary to cut it out and it was replaced with 10 rings. This again had to be cut out and it was replaced with 12 rings—and of this Mr. Baldwin says a portion must again be replaced. The bricks are of good quality; they are made on the spot from clay excavated from the tunnel. Latterly some very hard Staffordshire bricks have been procured to be used for the 3 rings nearest the face of the masonry. On one short piece, not more than 40 feet in length, several months were spent in endeavoring to complete it. Eight or ten feet of the lining came down in a mass. Mr. Baldwin told me he had to fill the tunnel almost solid with timber to hold the lining in its place, and afterwards to virtually *tunnel through* the timber again. The ends of timbers were crushed bodily into the sides of those against which they butted, and scarfed joints were driven against each other till they became nearly square. A peculiar tendency to decay in the timber was very remarkable. Fourteen inch timbers apparently good were

found in three weeks decayed one inch in depth. Mr. Baldwin said he could not believe it nor would others at first, but that the fact was unquestionable, and that the handles of picks left any length of time in the tunnel were evidence of the same thing.

The shafts had originally a lining of brick, 9 inches thick, but it is so pressed in, and the diameter so reduced, that it will eventually be removed and replaced with one 18 inches thick. The masonry is built as soon as possible after the excavation, so as to relieve the strain upon the timbers. The action against it, if it takes place at all, begins very soon. If an interval of two months elapses without its being noticed, it is no longer feared. The action at the top of the arch is slight, the principal effect is on the invert, which first rises in the centre, and then the sides follow inwards.

In reply to questions as to the mortar used, and whether he had tried cement, Mr. Baldwin told me that cement had been used in some places, but that they now gave the preference to lime mortar, because, not hardening so quickly, it receives gradually the first pressure and the bricks do not break so readily.

The section of the tunnel has been modified several times to meet the difficulties encountered. It was originally elliptic. The first alteration made was to lower the invert which shows such a tendency to rise. Subsequently the arch was lowered and flattened at top—each time approaching more and more the circular form—and the section now adopted is completely circular above the rails, with a very deep invert, and in fact very nearly circular throughout. The drawing furnished me by Mr. Baldwin [Plate VII.] being the result of careful measurements upon the tunnel, shows the original section and its modification, and the rising of the invert under the pressure. In this connection I may remark that on a subsequent visit to the *Hauenstein* tunnel in Switzerland, Mr. Burry, the Engineer of the Central Swiss Railway, told me that a very similar case had come to his knowledge on a tunnel in Wirtemberg, also in clay.

At the Sydenham Tunnel some of the shafts are worked by horse power, deeper ones by steam. A double rope raises a skip full of earth on one side and lowers one full of bricks on the other. A rolling platform on rails, is run over the mouth of the pit, from its side, when a skip has been raised just above it. The skip is lowered on to a small truck standing upon rails laid on the platform, and is from there run off to the edge of the spoil bank. The platform when rolled over the mouth of the pit completely covers it, so as to avoid accidents, and

there is a slit in it to receive the rope which runs down the shaft on the other side. The platform is worked by two men who roll it off and on, and remove and replace the skips. It is like a low platform car on four wheels.

The great difficulties here encountered render this tunnel very expensive. Some portions of it have cost as much as £120 or $600 per running yard. In general the London clay is considered a very bad material. The contract price paid for a large number of these tunnels on the great Northern Railway was £90 or $450 per running yard—and this was considered a fair price for such work.

This tunnel is built under the direction of Mr. Cubitt, the eminent engineer. The contractors are Messrs. Peto and Betts, well known all over Europe. Mr. Charles Watson, who is connected with their establishment and has a special supervision over the work, told me that the average progress at a face was about 22 feet a month, where there was no special necessity for driving the work, but that by using three gangs of workmen they could make a progress of 60 feet, or 20 yards a month, if there should be any necessity for haste. He fully confirmed the extraordinary fact of the decay of timber in the tunnel, mentioned by Mr. Baldwin, stating that he had himself procured and sent the timber to the tunnel, knew what it was, and refused to credit the fact of its deterioration until he had personally been there to examine it. In reply to my question as to the effect to be anticipated hereafter upon the timber used for the track, he said that since the driftways had been completed for the whole length of the tunnel, there had been a great change in this respect, and that with the ventilation which the large section would give them they did not apprehend difficulty in the future.

While I was in England I did not visit for the purpose of a personal examination any other tunnels besides those already described, as I heard of no others in progress which would be of peculiar interest, and was told that what I had seen was a fair specimen of the English mode of construction. I lost no opportunity, however, to converse with persons of skill and experience in relation to their own work, and to the project of the Hoosac. Mr. Lane told me that from his experience he preferred to make the driftway or heading at the bottom of the tunnel, and that the only way to hasten the construction was by numerous shafts. He knew of no machinery for tunnelling ever having been used in England, but in England there was no tunnel of the length of ours,

and no instance of such distances excavated without shafts. Of course at the Hoosac it would be necessary to furnish ventilation to the workmen during construction, and he advised that this should be done by exhausting from within, not by forcing from without, and did not think it would be a very difficult matter. The central shaft would certainly be required, both to save time and furnish ventilation, for with a summit like ours within the tunnel it was indispensable for the latter purpose, if unnecessary for any other other. These shafts are expensive, but the depth of ours though great is not extraordinary, and he mentioned one at the Pemberton pit in Sunderland which was 12 feet in diameter and 1,800 feet deep, which it took seven years to sink, and was said to have cost £100,000. In reply to my question whether he would not carry forward an open cut to 60 or 65 feet in depth before he began to tunnel—he thought not, that it would be better to begin the tunnel earlier, preferring an arch to a wide cut or to heavy retaining walls, both as safer and as less expensive.

The present section of our tunnel he thought decidedly too small—and that it would be vastly better to make it at once of the requisite dimensions, rather than to leave it to be enlarged hereafter.

The best mode of draining is by a covered culvert in the centre between the tracks. He knew of no case in England in which longitudinal drains had been built behind the masonry.

With Mr. Sacré, the engineer of the Manchester, Sheffield and Lincolnshire Railway upon which is the Woodhead Tunnel, nearly as long as the Hoosac, and originally of nearly the same section, with Mr. Richardson, engineer of the Bristol and South Wales Junction Railway, of whom I have already spoken, with Mr. McClean and his partner Mr. Stileman who enlarged the Lindal Tunnel some years since, both distinguished engineers in very full practice, with Mr. Watson, a gentleman of large practical experience, connected with Sir Morton Peto and Mr. Betts, who were themselves absent at the time of my visit, and with Mr. Thomas Brassey, probably the most successful and experienced railway contractor in the world, I had interviews in which I explained to them the condition and character of the Hoosac enterprise, showed them the profile of the mountain, the section thus far adopted, the grade of the road within the tunnel, the position of the proposed shaft, and exhibited to them specimens of the rock. Differing in some respects in their peculiar views of the details of construction, they all concur in the opinion that the present section of our tunnel is too small, and that the central shaft with such a line as ours is indispensable.

With Mr. Brassey I had long and satisfactory interviews. I had been previously told that of all men in England he was the one possessing the most practical knowledge and the largest experience upon the matters concerning which I had come to make inquiry, and I certainly found no one whose information was more ready, distinct and useful. There is hardly a country in Europe in which he has not executed very large and important works, and his contracts amount to millions.

After hearing from me a general description of the Hoosac Tunnel, its present condition, and the project generally, and looking at specimens of the rock, he spoke of it as a great work and one presenting some peculiar elements of uncertainty, because there is no work of such extent now completed. The only analogous one is that at Mont Cenis, which is still but in the early stages of its progress, and not much more advanced than ours. The tunnels I had already examined in England were amply sufficient specimens of ordinary work, and those of France which were completed works, some of them of his own construction, would show nothing more. The Hauenstein Tunnel in Switzerland, a long tunnel built by him in which more than one mile was completed from one end, and in which there are no shafts open, was one that it might be well to see.

Numerous shafts he thought quite unnecessary for ventilation. They make eddies and currents and interfere with each other. The passage of a train at quick speed is the best ventilator.

For our tunnel, with a summit in the centre, he thought a central shaft indispensable for ventilation if not for construction. It need not be very large, a diameter of 10 or 12 feet would be enough. There are some advantages in making it oval instead of circular. Such a shaft as ours in rock would require at least two and a half years—perhaps three years to sink it, and in England might cost £10,000, or $50,000.

In a tunnel in rock a chain, or 22 yards per month, is the greatest progress that can be made by hand labor, perhaps a safer calculation would be 18 or 20 yards. The size of the section would make no difference in the speed. There should be a heading as much as 9 feet square driven forward, this size being sufficient to allow the wagons to run in and out and to allow ventilation, and the speed at which the heading can be driven is the measure of your progress, because you can follow up with your full section with whatever number of workmen you choose, a larger section giving room for a larger number of workmen.

At a shaft like ours we ought to have a steam-engine of from 30 to 50 horse power, to be in readiness to deal with water.

The heading or driftway should certainly be at the bottom, so as to allow the use of wagons to remove the materials. The plan of breaking up in several places at once is a good plan, where you have to line with masonry, but if you are excavating in rock which requires no masonry it is unnecessary, because you may follow rapidly with the enlargement and keep nearly up to the end of your driftway, which is a great advantage as regards ventilation.

We should certainly have to ventilate for our workmen, but he has little doubt that with a central shaft there would be sufficient natural ventilation, without artificial aid, after the construction of the tunnel, but the shaft is indispensable.

The present section of the tunnel is decidedly too small. The original one is the least that ought to be allowed for such a tunnel, and he would be more inclined to enlarge it than to diminish it.

Our enterprise has all the contingencies and uncertainties of an untried project, and it would be unsafe to undertake it by contract. The Mont Cenis Tunnel, the only one analogous to ours, is a government affair and of national interest. In England nobody would engage *commercially* in constructing a tunnel which was to require ten or twelve years for its completion. The result is too remote for a financial scheme, and such things can only be done as matters of public policy.

As the general result of my observations in England, I find that tunnels are not considered such formidable works as they have generally been esteemed in our Northern States, and that there is scarcely a railway line of any length upon which they are not introduced. They are used not merely to pass through summits which it is impossible to pass over, but often where open cuts would have been perfectly feasible, and of less depth perhaps than they are in other parts of the railway. Local circumstances, the great value of the land required for a deep and wide cutting, the opposition of influential land owners to having their estates disfigured or their lands divided, the necessity of avoiding crowded thoroughfares near large cities, have all led to their adoption where no natural necessity resulting from the topography of the country would have rendered them the only resort of the engineer. This of course has influenced their character and the mode of their construction. While we have been discussing the best methods of making rapid progress from working the end faces, in

England the practice has been to multiply working shafts, and sometimes to omit work from the ends altogether, and complete the whole tunnel much in advance of the adjoining cuts. With few shafts or deep ones, this would be a difficult and expensive process, but shafts are made even as short as 45 or 50 feet, and very deep shafts are uncommon. The character of their rock cutting is very different from ours. In general the rock is worked much more easily than that upon our Northern railroads. The longest railway tunnels do not exceed three miles in length, and some of them are so short as to be but long bridges. In no one has machinery ever been used for drilling or excavating. In no one have artificial means of ventilation been required after their construction. In no one does the passenger in the train under any circumstances, as far as I could learn from information of others or by my own experience, suffer any inconvenience. In all of them workmen are employed without difficulty upon the necessary repairs, in some of them finding the work unpleasant, sometimes complaining that it is unwholesome, but performing it as other unpleasant or unwholesome work is performed. I did not find that the road-bed is in general more troublesome to keep in order than elsewhere. Gravel is preferred, and the timbers laid in it are said to be rather less subject to decay than in other parts of the track. The drainage is almost invariably by a covered drain in the centre. Inverts are used or dispensed with according to the character of the ground. Brick masonry appears to be more commonly adopted than any other, and sometimes for the arches where the side walls are of stone, almost invariably for repairs, or for new work after the railway is opened for use.

The English tunnels are straight and on a uniform grade, sometimes a very steep one. Some objection was made by English engineers to our grade at the Hoosac with a summit in the centre, which, if we sink a central shaft and work both ways, will cause the water to follow us and not to leave us. Their own practice, however, suggested a remedy. It is to begin the driftway where it leaves the central shaft, at the very bottom of the tunnel, and to carry it forward either level or slightly rising till it reaches the top of the section. It is evident that we could thus go forward for a half a mile without getting out of the limits of the section, as the grade falls but 13 feet in half a mile, and this is also greatly facilitated by our short level plane at the summit. Even if nothing more than this driftway were made, it would be of very great advantage to the work from the end face, which would

reach the driftway after half a mile less progress than if it had to be carried all the way to the shaft, and great assistance to the ventilation for the workmen would be obtained the moment it was reached.

Opinions are divided as to the use of shafts for ventilation after the tunnel is completed. The more general opinion seemed to be that, unless in very long tunnels, they were of no use and had better be closed, as they were rather an interference with the natural current which differences of temperature or prevailing winds would generally occasion, and with the great ventilating agency of quick trains. The tunnel was compared to a chimney, inclined to be sure, but in which the draught would be best with no openings in the sides. In a case like ours, however, a central shaft was considered indispensable.

In almost every tunnel a great many shafts have been closed—but I heard of none where a shaft had ever been afterwards opened for ventilation, unless it may be the small opening in one of the shafts above referred to in the Sapperton Tunnel, which was very inefficient or, to say the least, of very doubtful advantage.

The English engineers seem to have great preference for lining their tunnels with masonry, even in rock-cutting. They consider it far safer, dreading the effect of frost or other agencies on the face of the rock. This doubtless results in a measure from the character of the rock they deal with. In general I did not find that the tunnels left without masonry in rock-cutting were any more wet than they were elsewhere, and I was much surprised to find how much water passed through the masonry, in many places covering the arches with small stalactites.

The enlargement of tunnels in England has been made in two ways; by an actual enlargement of the original section as at the Lindal, and by the construction of a second tunnel parallel with and adjoining the first as at the Woodhead. Both plans have their advocates, but all concur in objecting to tunnels which require enlargement, and unhesitatingly advise a sufficient section at the outset.

Some English tunnels have been constructed in what seemed a short time, but the work was run from a great many faces resulting from the use of shafts. Twenty yards forward per month at one face is considered very rapid progress. I do not think the average progress has been nearly so much. I doubt if it has been half as much, if we estimate it by the time which elapses from the commencement to the completion of the construction.

As regards *cost*, such work is too various and uncertain in its character to be reduced to an average. I have had prices given me

varying from £25 to £50, that is from $125 to $250 per running yard for ordinary tunnels, but peculiar difficulties have in some instances raised the cost to £100—£130—and even £150, or $500, $650 and even $750 per running yard. Of course such estimates and prices are of little value to us, for the experience already obtained by work thus far done at the Hoosac Tunnel is for our purpose an infinitely safer guide.

HAUENSTEIN TUNNEL.

The Hauenstein Tunnel in Switzerland, on the Central Swiss Railway between Bāle and Olten, is a tunnel in the construction and use of which there are some peculiarities rendering it a work of unusual interest in connection with the special object of my inquiries. It is a long tunnel, being 2,496 metres* in length, equivalent to 2,729 yards, or more than a mile and a half; its construction was carried forward to the distance of 1,802 metres, or a mile and one-eighth, *from one entrance*, and it has *no ventilating shafts.*

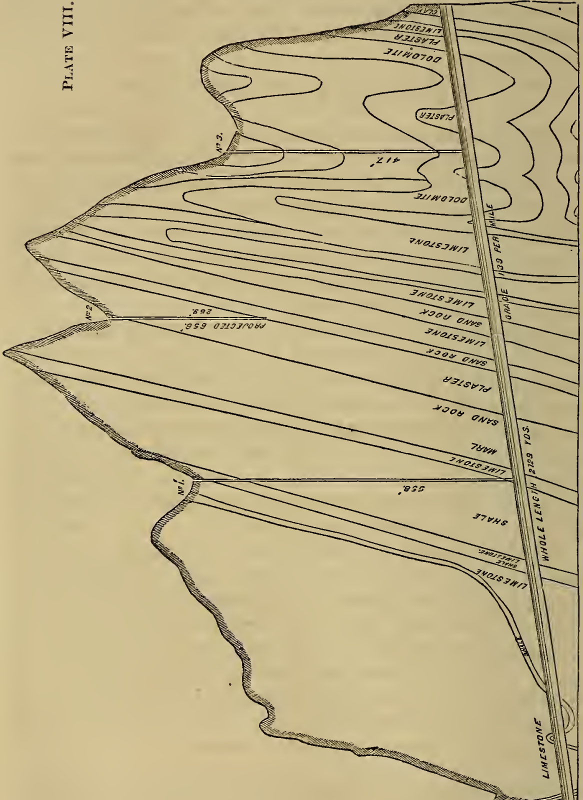
My attention was first directed to it by Mr. Brassey who built it, and who gave me a general account of it, and referred me for further particulars to Mr. William Watson, his foreman upon the work during the whole period of its construction, a highly intelligent practical man upon whose statements and recollection Mr. Brassey told me I could implicitly rely. I was fortunate enough to procure ample drawings illustrating its character and mode of construction, and afterwards made a personal visit to the tunnel and had an interview at Bāle with Mr. Burry, now the chief engineer of the line.

The tunnel passes through limestone, sandstone and shale, the various beds of which, sometimes regular and sometimes greatly contorted, are exhibited upon the longitudinal section [Plate VIII.] which accompanies this report. The tunnel has a double track, and is in section 26 feet wide and 20 feet high above the rails. In a small part of its length it has no masonry, the rock being sufficiently hard to dispense with it. In some places it has an invert, in others the invert is omitted. The drainage is in the centre by a covered channel. [Plate IX.]

* As the French metre is used not only in France but on the continent generally as the unit of measure upon public works. I append the following table:

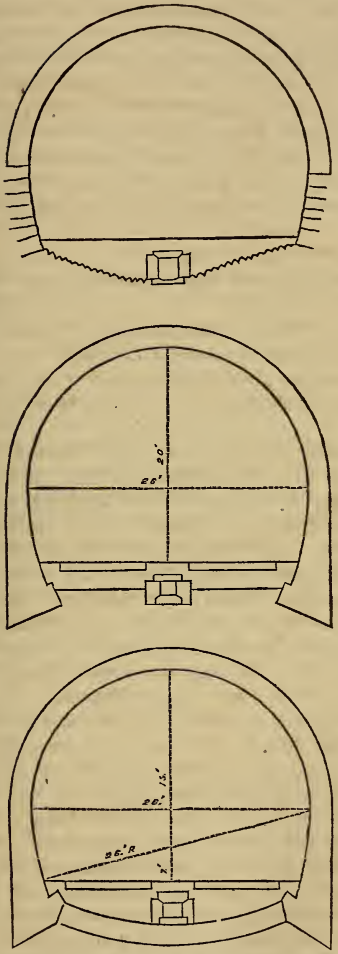
1 metre	= 3.28090 English feet.
1 metre	= 1.09363 English yards.
1 square metre	= 10.76431 English square feet.
1 cubic metre	= 35.31661 English cubic feet.
1609.32 metres	= 1 English mile.

PLATE VIII.



PROFILE OF HAUENSTEIN TUNNEL.

PLATE IX.



SECTIONS OF HAUENSTEIN TUNNEL.

The line is straight, and the grade uniform, from one end to the other, rising, from the south towards the north, at the rate of 1 in 38, or 139 feet per mile. At the south, or lower end, the tunnel is approached with a rising grade of 1 in 40, or 132 feet per mile, on which there are two curves of 300 metres, or about nine hundred and eighty-four feet radius. At the north end there is a level plane, 1300 feet in length, adjoining the tunnel, after which the road descends again, at the rate of 1 in 40. These excessive grades and curves give an idea of the topography of the country, which is one of singular beauty to the amateur of the picturesque, but of singular difficulty to the engineer.

Three shafts were originally projected —

No. 1, situated 1127 yards from the south end, and 558 feet deep.
No. 2, " 1668 " " " " 656 feet deep.
No. 3, " 2232 yards from the south end, and consequently 497 yards from the north end, and 417 feet deep.

The position of these shafts was determined by three depressions in the surface. If placed elsewhere, they must have been of greater depth.

No. 3, the shortest of these, was completed February 1, 1855, but it appears to have been used but little. Fifteen months afterwards, on the 6th of May, 1856, there had been an advance from the shaft of only about twenty-five yards towards the north, and thirty-six yards towards the south. At this date the work from the north, or nearest end face, which had then made an advance of 432 metres or 472 yards, reached that from the shaft, and the junction being effected, the work was thereafter carried forward from the end alone, leaving only 61 yards of the whole line constructed exclusively by means of this shaft.

No. 1, the next shaft in depth, was completed April 1, 1855, and work was rapidly driven from it in both directions.

No. 2, the deepest of the shafts, was commenced in the spring of 1854, at the same time as the others. Very great difficulties were encountered from the abundance of water, and the progress was extremely slow. In some months, the advance was less than two metres. On the first of August, 1855, it had reached the depth of only 269 feet, leaving 387 feet more to be accomplished. At this date, the work from shaft No. 1 was rapidly advancing in both directions, and the opening from the north end was making good progress. It was therefore decided to abandon any further attempt to sink shaft No. 2, as it was not likely to be finished in season to expedite the construction of the tunnel.

Shaft No. 1 had been sunk through a variety of strata, of differing firmness and character. A portion of it was lined with masonry, a portion left in rock, and a portion lined with timber. For the convenience of the work progressing from the foot of this shaft, a small forge was placed under it, where the workmen's tools were sharpened and repaired, the warm air and smoke ascending by the shaft, and serving, it was supposed, to assist the ventilation. The wood-work lining the shaft took fire, and burnt smouldering, without attracting attention, until it became so weakened as to give way to the surrounding pressure; it was broken through, and an enormous mass fell in, filling up the shaft, for the depth of 30 feet, and completely blocking up the whole tunnel. It was impossible to remove it. No means, speedy enough, could be found to rescue fifty or sixty unfortunate workmen, thus confined, and they all perished in their living tomb. The soil had been so loosened, and the injury to the shaft extended so far, that it was considered impossible to reopen it, and it was therefore abandoned.

The accident happened in December, 1855. At that time, an advance had been made from this shaft, of 284 yards towards the south, and 238 yards towards the north. The advance from the south end face was just up with it, and a junction was effected. The part of the tunnel obstructed by the fallen mass was reopened from that end, and the work thenceforward was driven from the south entrance until the 31st of October, 1857, when at the distance of 1802 metres, or 1970 yards, it met the advance from the north entrance, which had then been completed for a distance of 694 metres, or 759 yards.

These shafts were all 12 feet in diameter. When the works were completed, shaft No. 3, the only one then remaining, was closed, and the tunnel has now been in use for about four years, with no ventilation except from the ends.

The masonry of the tunnel is of limestone, brought for the purpose, that excavated not being suitable. No bricks were used.

During the construction, it was necessary to supply air to the workmen. This was done by a small four-horse power steam engine driving a fan, which forced in the air by a wooden trunk 15 inches square. There was a second supplementary fan, about eleven hundred yards from the south entrance, driven by a water-wheel, which was set in motion by the drainage water running down the tunnel, the excessive abundance of the water and the steepness of the grade allowing the use of this unusual contrivance. Of course this could not have been done if the work had been performed from shafts, and it

was an advantage, which tended to compensate for the necessity of working for a long distance from one end. Mr. Watson said that the mechanical engineer employed upon the works, told him he was confident he could ventilate for a distance of two miles with a ten-horse power engine, but that he should want an iron pipe to convey the air.

The large drawing, presented herewith, shows the mode in which the work was carried forward. The heading was about ten feet square, and run forward at the bottom. In working from the north end, that is, in working down the grade, of course the water was exceedingly troublesome, as it followed instead of leaving the work, and the method of raising the heading, within the limits of the section, as it advances, instead of keeping it parallel with the true grade, seems to have been adopted. Frequent wells were also made at the bottom for the water to accumulate therein. In hard rock cutting, Mr. Watson said he should prefer to make the heading at the top rather than at the bottom.

To expedite the work, which they had to drive as rapidly as possible, on account of the failure of the shafts, the heading was kept running forward night and day, with *four* shifts of men, and was usually from 150 to 200 yards in advance. From the heading, the material was broken up overhead, in a great many places, in the manner already described as sometimes practised in England. That is, the roof and sides of the heading were cut away and enlarged, and sections of masonry inserted; so that, with only two or four real faces for the advance of the heading, there were many more for the enlargement and the masonry. At one time, as many as 300 men and 12 horses were working from the south end alone, and at the various "break ups."

Mr. Watson thought, that in our Hoosac rock it would be possible to advance about twenty yards a month, and that if we had a shaft, we could make about the same progress at the faces run from the shaft as at those from the end, if we made proper arrangements to remove the materials excavated. In sinking the great central shaft at the Hoosac, he thought it would be impossible to exceed ten yards a month, and this could certainly not be done if there was any trouble from water.

The whole time consumed in the construction of the tunnel, was from four to five years.

The progress made in sinking the shafts was as follows: There is no record prior to June 1, 1854, at which time they had all been started.

		Metres.	
Shaft No. 1.	Depth, June 1, 1854,	34.50	
	Progress, in June,	5.40	
	July,	9.30	
	August,	17.20	
	September,	19.50	
	October,	23.40	
	November,	17.70	
	December,	16.50	
	January, 1855,	18.00	
			161 50

The remainder of the depth seems to have been excavated in connection with the main tunnel itself.

The progress in eight months was 127 metres, being an average of $15\frac{7}{8}$ metres, or 52 feet per month.

		Metres.	
Shaft No. 2.	Depth, June 1, 1854,	17.40	
	Progress, in June,	13.50	
	July,	3.60	
	August,	11.00	
	September,	11.55	
	October,	2.65	
	November,	1.20	
			60.90

It now seems to have been left, for there was an additional progress of only 3.60 metres, up to June 1, 1855. After that, in June, 1855, 8.70; July, 9.00; making in all 82.20 metres, when it was abandoned.

		Metres.	
Shaft No. 3.	Depth, June 1, 1854,	43.20	
	Progress, in June,	11.70	
	July,	11.10	
	August,	20.70	
	September,	12.00	
	October,	12.60	
	November,	6.30	
			117.60

At this depth the work was connected with that of the tunnel. The progress in six months was 74.40 metres, being an average of 12.40 metres, or nearly 41 feet per month.

For the progress in the tunnel itself, that at the foot of shaft No. 3 does not seem to be a fair criterion, as it evidently was interrupted and suspended at times. The progress from shaft No. 1, up to the time of the accident, was as follows:—

	Southward. Metres.		Northward. Metres.	
Previous to May,	12.00	. . . . . .	13.50	
1855, May,	20.70	. . . . . .	21.90	
June,	37.80	. . . . . .	19.80	
July,	36.90	. . . . . .	35.10	
August,	42.90	. . . . . .	38.70	
September,	40.80	. . . . . .	32.40	
October,	51.00	. . . . . .	33.30	
November,	17.70	. . . . . .	23.10	
	259.80		217.80	Total, 477.60

This is a progress of 451.10 metres in 7 months at two faces, or 32.22 metres, equivalent to nearly 106 feet at one face.

The progress from the south entrance, which, on the 1st of June, 1854, had been opened to the distance of 165 metres, was as follows: —

South End.		Metres.
June 1, 1854,	. . .	165.00
Progress, in June,	. .	24.00
" July,	. .	30.90
" Aug.,	. .	38.10
" Sept.,	. .	24.30
" Oct.,	. .	26.40
" Nov.,	. .	28.80
" Dec.,	. .	33.90
1855, " Jan.,	. .	38.40
" Feb.,	. .	47.10
" March,	. .	45.90
" April,	. .	46.50
" May,	. .	40.20
" June,	. .	45.60
" July,	. .	7.80
" Aug.,	. .	24.90
" Sept.,	. .	50.00
" Oct.,	. .	17.30
" Nov.,	. .	30.10
		765.20
Junction with face run southward from shaft No. 1, passing over space already completed from shaft No. 1., of		477.60
		1242.80

Continued		Metres.
	.	1242.80
Progress, in Dec., 1855,		26.80
1856, " Jan.,	. .	42.00
" Feb.,	. .	36.60
" March,	. .	21.00
" April,	. .	18.90
" May,	. .	14.40
" June,	. .	13.80
" July,	. .	16.20
" Aug.,	. .	14.40
" Sept.,	. .	14.10
" Oct.,	. .	14.80
" Nov.,	. .	30.10
" Dec.,	. .	31.00
1857, " Jan.,	. .	37.80
" Feb.,	. .	40.50
" March,	. .	56.00
" April,	. .	19.90
" May and " June,	}	21.40
" July,	. .	19.00
" Aug.,	. .	20.50
" Sept.,	. .	20.50
" Oct.,	. .	29.50
		1802.00

The progress from the north entrance, where an advance of 52.80 metres had been made, up to June 1, 1854, was as follows: —

NORTH END.	Metres.
June 1, 1854, . . .	52.80
Progress, in June, " July,	26.10
" Aug., . .	32.10
" Sept., . .	24.90
" Oct., . .	21.30
" Nov., . .	4.80
" Dec., . .	9.30
1855, " Jan., . .	4.50
" Feb., . .	6.90
" March, . .	5.10
" April, . .	16.80
" May, . .	33.70
" June, . .	9.50
" July, . .	21.00
" Aug., . .	15.00
" Sept., . .	44.70
" Oct., . .	27.30
" Nov., . .	18.00
" Dec., . .	18.90
1856, " Jan., Feb. March,	16.80
" April, . .	22.10
	431.60
Junction with face run northward from shaft No. 3, passing over space already completed from shaft 3, of	56.70
	488.30

	Metres.
CONTINUED . .	488.30
Progress, in May, " June, " and July,	21.70
" Aug., " Sept., " Oct., " Nov., " Dec.,	10.80
1857, " Jan., . .	19.00
" Feb., . .	20.50
" March, . .	6.00
" April, . .	8.40
" May and " June,	11.30
" July . .	24.00
" Aug., . .	26.00
" Sept., . .	23.50
" Oct., . .	34.50
	694.00

From the south entrance, the progress in 18 months, from June, 1854, to November, 1855, inclusive, was 600 metres, equivalent tc $33\frac{1}{3}$ metres, or 109.33 feet per month, at one face.

During the next 23 months, from December, 1855, to October, 1857, inclusive, after passing shaft No. 1, the progress was 559 metres, equivalent to 24.30 metres, or 79.70 feet per month, at one face.

From the north entrance, the progress in 19 months, from June,

1854, to December, 1855, inclusive, when there seems to have been an interruption in the work, was 339.90 metres, equivalent to 17.89 metres, or 58.68 feet per month, at one face.

In the last 10 months, from January to October, 1857, inclusive, the progress was 173.20 metres, equivalent to 17.32 metres, or 56.80 feet per month, at one face.

We see here, that the work from the north entrance, which was on a down grade where the water followed the advance, progressed much more slowly than that from the south entrance, where the water could run off. And we also see that the work from the south entrance advanced less rapidly in the last half, than in the first half, of the whole distance.

The whole distance executed from the two end faces alone, between June 1, 1854, and October 31, 1857, a period of 41 months, was 1744 metres, being an average of 21.27 metres, or nearly *seventy* feet per month, at one face.

My principal object in making a personal visit to the Hauenstein Tunnel was, to see the effect of the absence of shafts upon the ventilation.

The tunnel, as has been mentioned, is on a very steep grade. I first rode *up* through it, standing on the outside platform of a passenger car, at the rear of a passenger train. The tunnel was somewhat cold and damp, but otherwise there was nothing disagreeable in the passage, and I was not at all incommoded by smoke or steam. On reaching the Laufelfingen station, which is at the upper end of the tunnel, I did not notice any smoke issuing from the entrance.

Ten or fifteen minutes after passing up, I rode *down*, standing on the outside platform of a passenger car, at the rear end of a *freight* train, and therefore much farther from the locomotive. My experience was the same as before, except that after passing out of the tunnel I saw a great deal of smoke following out after the train.

The conductors of both these trains told me that there was usually a current of air through the tunnel, and that the smoke disappeared in fifteen or twenty minutes. Both complained of its being very wet from the dripping of water.

A few moments after I had come through the second time, I saw a freight train with two locomotives just starting to go up, and was told that heavy freight trains like that, with two locomotives, going up the grade, produced by far the worst effect upon the air of the tunnel. Accordingly, I started very early the next morning with a heavy freight train, drawn by two densely smoking locomotives, burning coal. I

placed myself at about the centre of a long train, in a covered freight car with a door at each end, besides doors about eight feet wide on each side, all of which were purposely thrown wide open, and I stood at the middle doors. The day was dark and foggy, with a little mist falling. Altogether, the circumstances seemed to me to combine to give me an unpleasant trip, and the men upon the train, rather amused at my desire to take the very worst of it, told me I should be satisfied. The train moved slowly — about ten miles an hour. The passage was disagreeable, certainly, but it was perfectly endurable, and I have been much more troubled for respiration in a smoky room than I was on this expedition.

When we emerged from the mouth of the tunnel, very dense volumes of smoke instantly rolled out after us, so filling the air that the entrance was invisible at the distance of 50 yards outside. I watched it rolling out for about twenty minutes, when it rapidly subsided, and presently ceased entirely, leaving the whole entrance, and apparently the interior, quite clear. I walked a few yards into the tunnel; a moderate current was blowing through it towards me, and had evidently driven out the smoke.

In about three quarters of an hour after this third trip, I returned again *down* the tunnel in a light passenger train, taking a passenger's usual seat. In the car there was not the slightest perception of smoke or bad air. I could distinctly see the track for some distance after entering. Workmen were at various places, some near the centre of the tunnel, and their lights were bright and clear. Evidently the smoke of our freight train had all passed out.

About half an hour afterwards, I again went *up* the tunnel in a passenger's seat in a passenger train. The train was a heavy one. The air at Olten was still damp and foggy. The train moved slowly, and the passage took nearly six minutes. There was not the slightest discomfort to passengers from any cause.

At the upper end, we found a heavy merchandise train standing ready to pass down, for on this, as on every other railway I have seen, two trains are never allowed to be within the tunnel at the same time.

The traffic requires here 20 trains a day each way — 40 in all — exclusive of the return of the assistant engines.

A wooden screen covers the upper part of the arch at each entrance, descending as far as it may without interfering with the smoke-pipe of the locomotives; and there are canvas curtains which may be drawn across the entrance at pleasure, and are used in winter to keep out the cold.

The road bed is excellent gravel, and the rails are laid on wooden cross ties. The tunnel is very wet, much more so than any other I have ever seen, and the water drips copiously through the joints of the masonry.

At Bale, I called on Mr. Burry, the chief engineer. He says that occasionally the smoke remains a long time and is troublesome to the workmen, and that he has sometimes questioned whether a shaft would not be an advantage. At times there is a strong current through, so strong that it would be an inconvenience to the trains, if not checked by the curtains. The greatest trouble, however, has arisen from the water which drops upon the track, and forms ice upon the rails in winter. This gave at first a great deal of annoyance, but the evil is much diminished by the use of the curtains, which keep out the cold. In other respects the track in the tunnel is kept in order as easily as any where else. Repairs of any magnitude are made mostly in the night, when the trains are not running.

The result of my visit tended to confirm the opinion expressed to me in England, that in a tunnel on a uniform grade, of not excessive length, ventilating shafts are not necessary, and that a direct current will pass through the tunnel more readily without them than with them.

The tunnel was built by Mr. Brassey, by contract, at the price of 1750 francs per running metre. The difficulties encountered from water, and the extra expense of driving forward the work with unusual speed from the end faces, to compensate for the absence of shafts, made its actual cost amount to 2100 or 2200 francs per metre, or about $400 per running yard.

TUNNELS IN FRANCE.

Upon the railways now in operation in France, there are many tunnels of an interesting character, some of them of great length. Among those most worthy of notice, are the St. Martin, Nerthe, Blaisy, Arschwiller, Rilly, Alouette, and Lamotte.

TUNNEL OF ST. MARTIN D'ESTREAUX.

This work, which is upon the Bourbonnais railway, is described in great detail in Vol. XXVI., Série 3, of the *Annales des Ponts et Chaussées.* It is the only French tunnel of which I could find any published description. I have brought the volume for the use of the Commissioners, and would refer them to it for the details, which are there given at great length. It is 1380 metres, or 1509 yards long, and is constructed through hard porphyritic rocks. In section, its extreme width is 25 feet 3 inches, and its height above the rails 19 feet 4 inches. It was built from ten shafts, of which four only were left open after its construction. Their depth ranged from 70 feet to 176 feet. They were rectangular in section, 14 feet 9 inches by 6 feet 7 inches in the clear, and were divided into three separate compartments, one for the ascent and one for the descent of materials, and the third for pumps and ventilation. The weekly progress made in sinking these shafts was from 2.79 feet to 5.02 feet. The cost of the tunnel was 2600 francs per running metre, a cost which the engineers thought higher than it ought to have been. This is equivalent to $475 per running yard. The average progress, in running forward the headings, was 4.40 feet per week at one face,—and there being 18 faces, this is equivalent to 79.20 feet advance per week at the whole. At this rate, the heading or driftway, for the whole length, would have been completed in about thirteen months. Yet the time occupied in the construction of the whole work was five years from the date of starting the shafts. There was an interruption of about six months, during this period, leaving *four and a half* years of actual work.

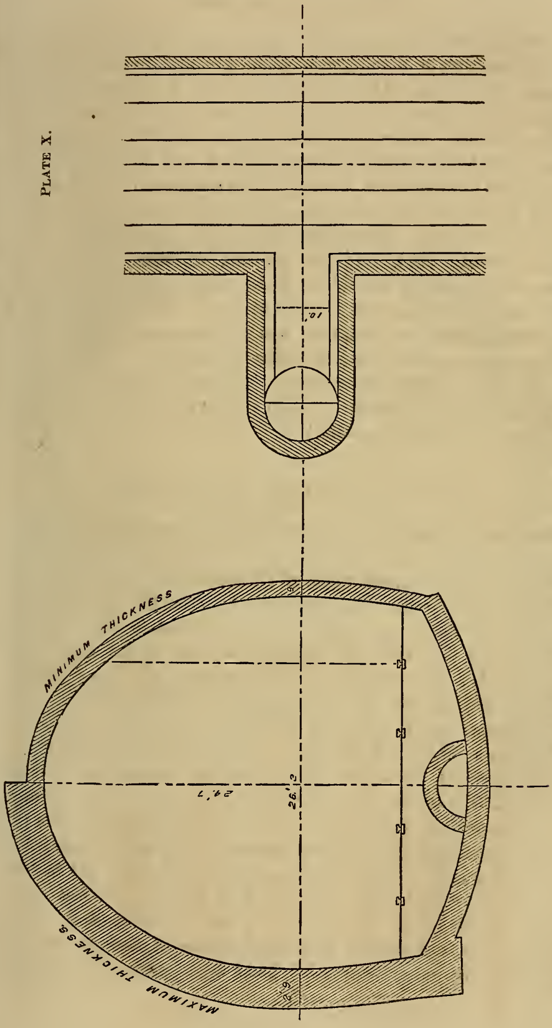
TUNNEL OF THE NERTHE.

The tunnel of the Nerthe, on the railway between Marseilles and Avignon, is 4,639 metres, or very nearly three miles in length. In section it is 26 feet 3 inches wide at the widest, and 24 feet 7 inches high above the rails. It has 24 shafts, which are not over the centre of the tunnel, but about 30 feet on one side. They communicate with it by lateral galleries, 10 feet in width, and as high as the tunnel itself. These shafts are circular, about 10 feet in diameter, and have all been left open. The two ends of the tunnel are nearly at the same level. From the Avignon entrance, the grade rises towards the centre at the rate of 1 in 500, and from there descends towards the Marseilles entrance at the rate of 1 in 1,000. The highest point, in the centre, is about fourteen feet above one entrance, and eight feet above the other. It passes through marl, dolomite, lias, and various limestone formations. For 950 yards of its length it is in rock cutting, where arching is unnecessary. The remainder is lined with masonry. The whole tunnel was completed in three years, and its cost was 2,254 francs per running metre, or $412 per running yard. The shafts vary in depth from 65 to 623 feet. The following table will show the cost of sinking them, and is interesting, as exhibiting the increased cost per foot as they go deeper. It does not include the cost of the wooden curbs or of the masonry. [PLATE X.]

COST OF SINKING SHAFTS.

			Cost per Foot.			
Shaft.	Depth.	Average cost per foot.	From 0 to 197 feet in depth.	From 197 to 328 feet in depth.	From 328 to 459 feet in depth.	From 459 to 610 feet in depth.
	Feet.	$	$	$	$	$
1 to 5	67	8.88	8.88			
6	200	10.97	10.97			
7	178	12.80	12.80			
8	252	13.72	13.47	14.70		
9	345	16.46	15.06	18.41		
10	292	15.85	15.24	17.31		
11	387	16.77	15.24	18.29	19.81	
12	482	16.77	15.55	18.60	21.34	
13	552	16.77	13.05	16.10	19.76	22.70
14	623	16.77	11.58	14.63	18.29	24.06
15	519	18.29	13.60	16.64	25.91	
16	472	15.85	13.05	16.10	19.81	
17	469	15.85	13.29	16.34	19.69	
18	375	15.24	13.78	16.83	18.29	
19	395	12.19	10.42	13.47		
20	489	13.41	10.97	14.02	15.24	
21	467	18.29	15.73	18.78	16.02	
22	361	15.24	13.78	16.83		
23	299	15.85	14.94	17.51		
24	258	13.41	13.41	13.41		

PLATE X.



TUNNEL OF THE NERTHE.—Section and Plan at a Shaft.

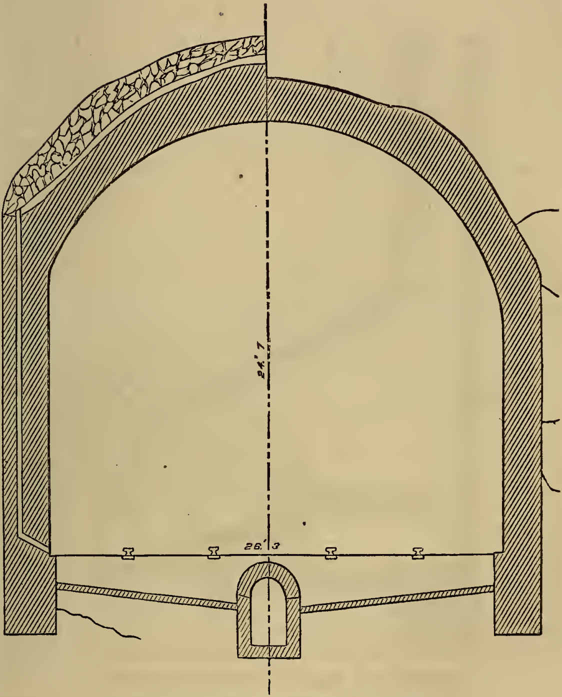
TUNNEL OF BLAISY.

This fine work is on the line of railway from Paris to Lyons. It is 4,100 metres, or 4,483 yards, about two and one half miles in length. In section, it has an extreme width of 26 feet 3 inches, and a height above the rails of 24 feet 7 inches. It had 20 shafts, of which 10 are now closed; every alternate one being left open. These shafts were only about 650 feet apart, and nine of them were from 515 to 643 feet in depth. They are not over the centre of the tunnel, but about 32 feet on one side, and connected with it by lateral galleries. The tunnel passes, for a large portion of its length, through marl, then through lias, dolomite, and gypsum. There are recesses in the side walls for the workmen, not at equal distances, but averaging one in every 55 yards. The drainage is by a covered channel in the centre, and in some parts there are also drains behind the walls, leading to the central drain. The cost of the tunnel I was unable to ascertain. The annexed figures will show its section, and the manner in which the shafts are connected with the tunnel. [PLATES XI., XII.]

TUNNEL OF ARSCHWILLER.

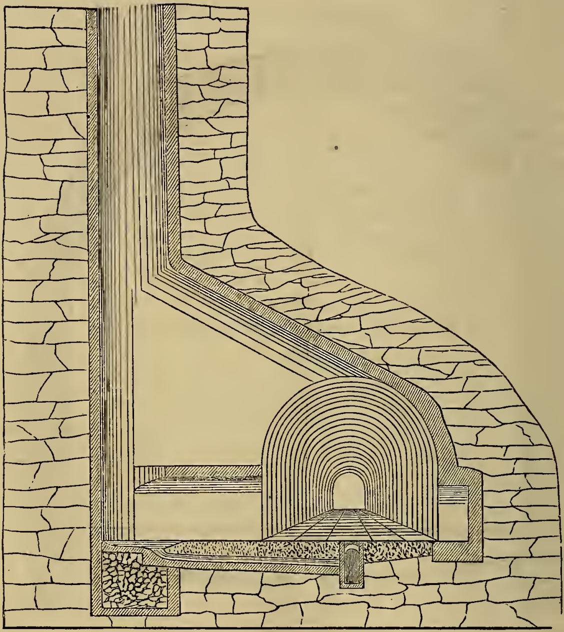
The tunnel of Arschwiller, on the railway between Paris and Strasbourg, is 2,678 metres, or 2,928 yards, more than a mile and a half in length, with an extreme width of 24 feet 3 inches, and a height of 18 feet above the rails. This tunnel, and that for the canal from the Marne to the Rhine, are built close together, and in fact form but one. Where they enter the mountain, they are at the same level, and a double arched entrance — the intervening pier being only 22 feet in thickness, and the arches precisely similar — receives them both. The canal was built first, and it is level and straight for its whole length, which is 2,521 yards. It diverges from the line of the railway tunnel at the rate of 26 in 1,000 feet, so that, at its other extremity, it is about sixty-six yards further from it than at their common entrance. From there the open canal turns again towards the line of the railway, and presently crosses it. The railway tunnel has a descending grade from the common entrance at the rate of 1 in 200, so that in its whole length of 2,928 yards it falls about 44 feet *below* the level of the canal. This allows it to pass *under* the canal, where the lines cross each other, a short distance before it emerges from the mountain at its western entrance. There are 13 galleries or passages

PLATE XI.



SECTION OF TUNNEL OF BLAISY.

PLATE XII.



TUNNEL OF BLAISY.—Section at a Shaft.

running from one tunnel to the other; the first one being level, and the others descending by steps from the canal to the railway, as the latter gradually falls. When the railway tunnel was commenced, the canal tunnel was in progress. Six shafts had been completed; and a heading run through its whole length. Use was therefore made of the canal works, already so far advanced, to facilitate the construction of the tunnel for the railway. The part of it which passes under the canal was built in an open cut, and arched and covered before the completion of the canal.

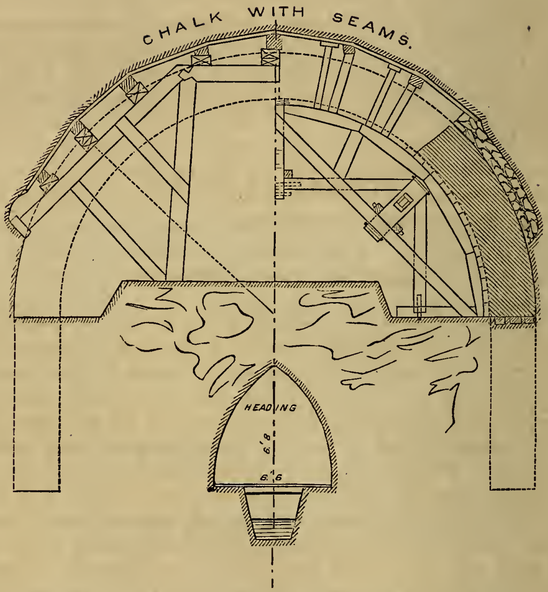
The length of time consumed in the construction of the Arschwiller Tunnel was very great, being no less than 7 years and 9 months from the commencement to the close of the work. The cost was moderate; amounting to 965 francs per running metre, or $176 per yard in length.

TUNNEL OF RILLY.

The tunnel of Rilly is on the Rheims branch of the line from Paris to Strasbourg. It is 3,450 metres, or 3,772 yards, a little more than 2 miles in length. Its extreme width is 24 feet 3 inches, and its height 19 feet 2 inches above the rails. Eleven shafts were commenced for its construction. Two of them were given up unfinished, on account of the difficulties encountered, principally from the abundance of water. Four were closed after the completion of the work, and the other five remain open. In some of the shafts the water was so troublesome that it became necessary to use for curbs cast iron cylinders, 5 feet in diameter and about 3 feet long, bolted together. A small heading was first run in the centre, through the whole length of the tunnel, and the water in some of the shafts was got rid of by boring down to this heading, through which it then escaped. The shafts were rectangular, 6 feet 6 inches by 13 feet in section, and divided into two compartments. The tunnel passes through the chalk formation. The arches were generally built first, the excavation being commenced at top, and the side walls were inserted afterwards, as shown in the annexed figure [PLATE XIII.]

The time consumed in the construction of the tunnel was 3 years and 4 months, and the cost was only 721 francs per metre, or $132 per running yard. It is lined with masonry throughout its whole length, the thickness being 20 inches in compact chalk and 32 inches in that which was seamy. In the latter material great precautions were necessary to avoid the falling in of large masses.

PLATE XIII.



TUNNEL OF RILLY.—Section showing Mode of Construction.

TUNNEL OF ALOUETTE.

This tunnel is upon the Orleans railway. Its length is 1,235 metres, or 1,350 yards. Its extreme width is 25 feet 7 inches, and its height above the rails 20 feet. It passes entirely through clay, where it was originally intended to have been an open cut; but the material was so subject to slides in wet weather, that a tunnel was found necessary for the security of the track. It was therefore built in an open cutting, and subsequently filled over. There are 21 large shafts or openings, 18 feet 6 inches in diameter. The pressure of the clay at the sides is so great, that the walls, in some places 5 feet 3 inches thick, were further strengthened by counterforts 8 feet 4 inches square. To relieve the tunnel from the water there are three parallel drains, one in the centre and one at each side under the road bed, and blind drains of loose stone behind the side walls. Its construction occupied 23 months, and its cost was 1,670 francs per running metre, or $305 per yard in length. About 660 yards of the tunnel are on a curve of large radius.

TUNNEL OF LAMOTTE.

The tunnel of Lamotte, on the railway from Paris to Caen, is 2,560 metres, or 2,799 yards, more than a mile and a half, in length. In section, its extreme width is 24 feet 11 inches, and its height above the rails 22 feet. Of its length, 931 yards are lined with masonry, 676 yards left in rock, and 1,192 yards built with side walls only. It passes mainly through marl, and for a short distance through chalk and green sandstone. There is a slight rise from each entrance towards the centre. At the distance of about 500 yards from one entrance there is an open cut 22 yards in length. Eleven shafts were used for its construction, of which 2 were at the entrances, 2 more were subsequently closed, and 7 remain open. Its construction occupied 2½ years. Its cost was 984 francs per running metre, or $180 per running yard.

The practice of the French engineers, in the construction of tunnels, differs in some respects from that of the English. In commencing the construction, they sometimes run forward two small headings to receive the side walls, as shown in the drawing of the Chézy Tunnel, and complete these walls before beginning the excavation for the whole section. In other cases, the upper part of the tunnel is first

opened and the arch built; the space for the side walls is then excavated, the arch propped with timber, and the walls constructed underneath it, as shown in the section of the Rilly Tunnel. It is also very common, I had almost said universal, to cover the masonry of the arch with cement or bitumen, or some impervious material, to keep out the water. Drains are sometimes made behind the walls, with outlets to the central drain. At the tunnel of Livernan, on the Orleans railway, large cables of straw were placed against the rock to lead off the water, and the masonry was built up around them.

In building shafts, the French engineers prefer to place them on one side, and not over the centre of the tunnel, partly because they consider it more convenient for purposes of construction, and partly because they think it safer for the track, which is thus less exposed to accident or ill-will, or the troubles arising from wet or dripping shafts.

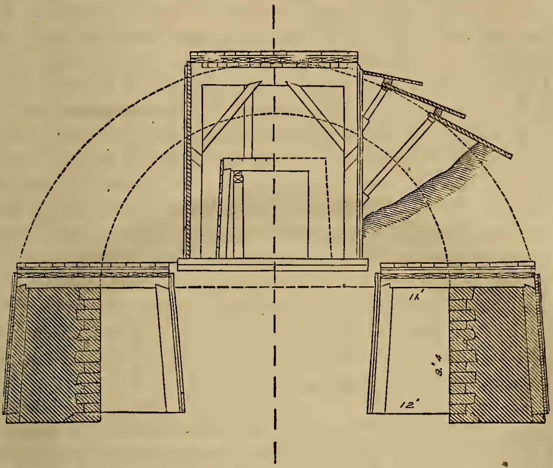
The thickness of the walls and arches, as well as the shape of the section, are varied to meet the requirements of various soils and the direction and force of the pressure to be counteracted. The section given of the tunnel of Hardelot shows a form adopted in a soft, moving clay, where the tunnel was built as the only security against dangerous slides in a deep cutting. [Plates XIV., XV.]

The French engineers are not afraid to construct tunnels on a curve. The tunnel of Hoffmuhl, 247 metres in length, the tunnel of Lutzelbourg, 439 metres in length, the tunnel of Montretout, 168 metres in length, the tunnel of Bourg la Reine, 204 metres in length, are either wholly, or almost wholly, on curves of about 2,500 feet radius. The tunnel of Fesc, 167 metres long, is on a curve of about 800 feet radius. And the tunnel of Vierzon, 208 metres long, is on a *reversed curve*, one radius being 3,280 feet, and the other 4,100 feet.

With the exception of the description of the tunnel of St. Martin, above referred to, I found no published account of the tunnels of France. But as the French engineers of the Ponts et Chaussées are members of a corps in the public service, and report directly and minutely to the central administration at Paris, a large body of statistical information is there collected, the accuracy of which may be relied on. It is from these unpublished documents, which are there prepared for the use of the government engineers, and to which I obtained access through the kindness of a friend belonging to the corps, that I have obtained most of the details which I have given above.

From the same source of information, I have also prepared the following table, which shows some of the characteristics of a large number of tunnels constructed in France: —

PLATE XIV.



SECTION OF THE CHEZY TUNNEL.

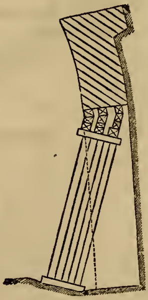
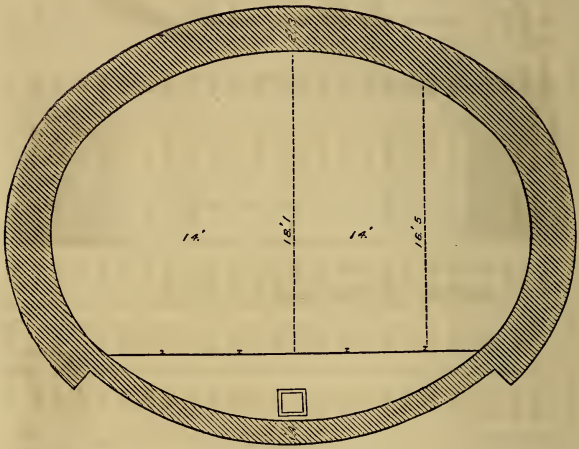


PLATE XV.



SECTION OF THE HARDELOT TUNNEL.

NAME OF TUNNEL.	Whole length. Yards.	Greatest width. Feet.	Height above rails. Feet.	Number of shafts used.	Section in the clear above the rails. Sq. Feet.	Cost per running yard. Dollars.	Time in construction. Months.	
Chalifert,	184	24.27	18.04	0	365.84	440	18	Marl and sandstone.
Armentieres,	718	24.27	18.04	1	365.84	289	35	Marl and limestone.
Nanteuil,	1,033	24.27	18.04	0	365.84	301	41	Marl.
Chezy,	496	24.27	18.04	0	365.84	417	32	Sand and clay.
Pagny,	626	24.27	18.04	0	369.28	235	33	Marl and limestone.
Foug,	1,227	24.27	18.04	2	374.77	250	37	Oxford clay.
Arschwiller,	2,928	24.27	18.04	6	374.77	176	93	Sandstone.
Hoffmuhl,	270	24.27	18.04	0	374.77	208	48	Sandstone.
Lutzelbourg,	480	24.27	18.04	0	374.77	165	52	Sandstone.
Bas Rhin, 1,	437	24.27	18.04	0	377.78	129	24	Sandstone.
Bas Rhin, 2,	539	24.27	18.04	0	377.78	135	48	Sandstone.
Haut Barr,	331	24.27	18,04	0	377.78	152	48	Variegated sandstone.
Rilly,	3,772	24.27	19.19	11	404.15	132	40	Chalk.
Place de l'Europe,	200	43.30	24.67	0	869.08	314	12	Four tracks, } under streets.
Place de l'Europe,	175	24.27	17.71	0	362.61	274	9	Two tracks, } under streets.
Batignolles, } double,	364	24.27	19.68	1	413.08	246	18	Gypsum.
Batignolles, } double,	364	24.27	19.68	1	413.08	246	18	Gypsum.
Terrasse St. Germain,	330	24.27	19.68	0	413.08	90		} Clay and sandstone.
Parterre St. Germain,	104	24.27	19.68	0	413.08	90		} Clay and sandstone.
Montretout,	183	24.27	19.68	3	413.08	397	13	Sand and marl.
St. Cloud,	551	24.27	19.68	10	413.08	399	15	Marl, clay, gypsum.

NAME OF TUNNEL.	Whole length. Yards.	Greatest width. Feet.	Height above rails. Feet.	Number of shafts used.	Section in the clear above the rails. Sq. Feet.	Cost per running yard. Dollars.	Time in construction. Months.	
Rue de Noailles,	50	22.96	21.32	0	432.98	219		
Rue St. Martin,	106	26.24	18.04	0	398.12	201		
Etangs Gobert,	153	25.58	19.02	0	412.32	259	12	Sand.
Hardelot,	201		18.04	0		320	18	Clay.
Belleville,	1,230	24.92	19.68	7	423.30	192	22	Clay and plaster.
Charonne,	1,116	24.92	19.68	7	423.30	201	22	Wet clay and plaster.
Bourg la Reine,	223	26.37	17.71	0	391.02	176	28	
Alouette,	1,350	25.58	20.00	21	428.68	305	23	Clay.
Vierzon,	227	25.58	19.35	0	332.81	189	13	
Boubard,	640	25.91	19.68	4	419.64	364	24	Clay and limestone.
Jéraphie,	768	25.58	19.35	3	424.27	385	86	Hard granite.
Combeau,	256	25.58	19.35	0	424.27	394	86	Hard granite.
Laurières,	870	25.58	19.35	1	424.27	373	90	Granite.
Nouaillas,	85	25.58	19.35	0	424.27	362	33	Granite.
Nouaillas,	96	25.58	19.68	0	424.27	362	33	Granite.
Poitiers,	350	26.24	18.20	3	440.30	230	21	Lime, sand, clay.
Bachées,	465	24.60	18.20	1	381.98	189	26	Marl.
Plans,	547	24.60	18.20	3	381.98	165	17	Oxford clay and limestone.
Angoulême,	853	24.60	18.20	0	381.98	183	33	Marl, lime.
Livernan,	1,601	24.60	18.04	4	381.98	205	53	Limestone.
Lormont, 5,	1,290	25.25	18.04	0	385.42	291	42	

NAME OF TUNNEL.	Whole length. Yards.	Greatest width. Feet.	Height above rails. Feet.	Number of shafts used.	Section in the clear above the rails. Sq. Feet.	Cost per running yard. Dollars.	Time in construction. Months.	
Folies Siffait,	18	24.27	18.04			194	36	Boulder.
Saulsaie,	78	24.27	18.04			79	48	
Clermont,	109	24.27	18.04			233	48	Hard gneiss.
Laroche,	46	25.58	19.02		411.46	182	14	Sandstone.
Boissy,	873	25.68	19.68	10	444.93	519	33	Clay and marl.
Martainville,	310	26.57	19.68		416.41	136	14	Marl.
Navarre,	207	24.92	19.68		416.95	134	14	Chalk.
Conches,	277	25.00	21.65		439.	204	15	Clay and sand.
Bernay,	371	25.00	19.68		413.72	139	9	Chalk and marl.
Lamotte,	2,799	24.92	21.98		519.71	180	30	Chalk, marl, sandstone.
Nerthe,	5,072	26.24	24.60	24		412	36	Limestone.
St. Louis,	520	26.24	24.60	2		284		Clay.
Beaucaire,	327	26.57	17.22	3	392.42	82	18	Limestone.
Fesc,	183	26.24	17.88	0	396.51	237	12	Lias.
Ners,	420	26.24	17.58	0	379.29	120	18	Limestone.
Boucoiran,	151	26.24	15.65	0	380.69	158	12	Limestone.
Tourmagne,	24	27.88	19.02	0	460.74	62	3	
Sempanges,	392	24.67	21.65	2	469.14	285	36	Marl.
St. Pierre,	711	25.68	19.35	3	422.22	236	18	Marl.
St. Martin,	1,509	25.25	19.35	10	415.34	475	60	Porphyritic rocks.
Blaisy,	4,483	26.24	24.60	20				Limestone.

In thc foregoing table the area of section given in square feet is the *area in the clear above the rails.* The whole section excavated, including road bed and masonry lining would be ordinarily from 20 to 30 per cent. more than this.

The section originally proposed for the Hoosac Tunnel, as shown by the drawing appended to this report, had an area of 422 square feet; and that subsequently adopted, and with which the tunnel has been commenced, has but 231 square feet.

In conversing with French engineers in relation to the Hoosac Tunnel, I found a most decided opinion that the central shaft would be indispensable, and equally decided objections to the small section. Mr. Chaperon, the engineer in chief of the line from Paris to Lyons and the Mediterranean, in speaking of a large section as essential for ventilation, told me of a tunnel originally built on the St. Etienne railway, in the south of France, about 1,400 metres in length, only about 10 feet in width, and high enough to admit the passage of locomotives, and said it was perfectly intolerable. To use his own expression, it was "the smoky torture." Fortunately for the travelling public the tunnel fell in, and was thereupon abandoned. Other lines have taken its place.

There was a good deal of difference of opinion among those with whom I conversed as to the monthly progress possible by hand labor in a rock like ours at the Hoosac Mountain. The highest estimate was about 60 feet, and from that down to less than 30 feet. I suspect the truth to be, that some engineers depend upon what can be done in a month of successful and uninterrupted labor, and others think only of the whole time to be consumed from the beginning to the end of a great enterprise. There is a wide range between the two.

TUNNEL UNDER THE ALPS AT MONT CENIS.

The tunnel now in progress under the Alps at Mont Cenis, for the purpose of connecting France and Italy by a continuous line of railway, is by far the greatest and boldest work of the kind ever yet undertaken. As you approach the Alps from the French side, the last forty or fifty miles of railway before reaching St. Michel, the present terminus, pass through a wild and mountainous region, presenting formidable obstacles to the engineer. Sharp curves, steep grades, and tunnels innumerable are rendered absolutely necessary by the character of the country, these tunnels being generally through

spurs of the mountains which project into the narrow gorge through which the line winds its way, and therefore often admitting the use of lateral galleries, running out horizontally, instead of vertical shafts, to facilitate their construction. At St. Michel travellers leave the railway car for the diligence, and after a tedious ride of about eight hours, making the ascent of Mont Cenis with the assistance of 12 mules added to the horses, reach Susa, on the Italian side, whence a railway runs direct to Turin, and there connects with all the lines of the Italian peninsula.

The present project is to continue the line of railway from St. Michel to Modane, a distance of some ten miles, following in general the course now pursued by the travelled road. At Modane is situated the northern entrance of the tunnel, the line of which turns abruptly, crosses Mont Cenis at the narrowest ridge, and comes out at Bardonnèche, on the Italian side, much to the south of the travelled road. From there it is to be connected by a railway 25 or 30 miles in length, either with the present line at Susa, or with some point on that line nearer Turin, as may be found most expedient.

Preliminary surveys for these portions of railway have been made, but nothing more. Nothing whatever has been expended on their construction. They are difficult lines to build, but these difficulties disappear before those of the great work of which they are to form the approaches; and until that shall have been brought nigh towards its completion, or at any rate to such a stage of its progress that its completion shall be neither doubtful nor remote, it has been thought best to devote all available skill and money to the tunnel itself, from which they are to derive their value.

The work is a national work, and not a commercial speculation of individuals. It was originally undertaken by Sardinia, within whose territorial limits it was then wholly included. The cession of Savoy to France brought nearly half the tunnel into French territory, and by the convention establishing the new boundaries between France and Italy it was stipulated that this great national work should be continued, should remain exclusively under the control of the Italian engineers, and that France should pay into the Sardinian treasury its proportion of the cost, according to an estimate then made and considered final, and fixed at 3,000 francs for each running metre, equivalent to $550 for each running yard of its length in French territory. The work has remained, therefore, as it was, under the exclusive direction of Mr. Gràttoni and Mr. Sommeiller, the engineers; and a French commission of engineers visit the work from time to time, by

order of the French government, to view its condition, ascertain its progress, and vouch for the amount to be paid to Sardinia.

The Italian engineers told me that throughout all the earlier doubts, perplexities, and embarrassments attending the first stages of a new and bold enterprise, exposed to criticisms, sometimes ignorant, sometimes sincere, and sometimes malevolent, on the part of politicians and professional men, they had constant, earnest, and sanguine support and encouragement from that enlightened statesman, Count Cavour, and they naturally speak with a little exultation of the fact that the work remains still in their hands, in spite of political changes; that its pecuniary resources are furnished by the empire of France as well as by the kingdom of Italy; that their own responsibility and relations are as before wholly to their own government; and that although French engineers visit their work, which they may freely criticise if they see fit, yet it is without any powers of authoritative criticism or control which might interfere with the practical exercise of their own judgment and experience in its prosecution.

Mr. Grattoni is an Italian engineer of distinction, connected not only with this, but with other important works. Mr. Sommeiller gives to this alone his whole time and thoughts, and has exclusively devoted himself to the mechanical department. The peculiar methods employed for the prosecution of the work, by the use of compressed air, the whole system of compressors, air pumps, and drilling machines he claims as his own invention, and to him must ultimately belong the credit of their success or the discredit of their failure. If he is unsuccessful, millions will have been squandered on a visionary project. If he succeeds, he will have solved a problem at which most men shook their heads, and declared it incapable of solution.

The line of the tunnel, as now laid out, is straight from end to end. Eventually, and after its first construction, a curve will be introduced at each end, by a very short supplementary work, in order to make a better junction with the tracks at those points. It is 12,220 metres, or 7 miles and 1,044 yards in length. From the French entrance at Modane the grade rises at the rate of 22.20 feet per 1,000, or 117.22 feet per mile, for a distance of 6,110 metres, or just half the length of the tunnel. It then falls towards the Italian entrance at Bardonnèche, at the rate of six inches per thousand feet, or 2.64 feet per mile. The rise from the French entrance to the summit is therefore 135.64 metres, or 444.90 feet, and from there the fall to the Italian entrance is 3.06 metres, or 10.04 feet, leaving the mouth of the tunnel on the Italian side about 435 feet higher than that on the French. Strictly

speaking, this is a case of a *summit* within the length of the tunnel, as we have at the Hoosac, but it must be noticed, that the fall from this summit in one direction is only 10 feet, which is less than half the height of the section, so that a line drawn on a level from the track at the summit towards the Italian entrance would come out of the tunnel about 11 feet below the top of the arch. This is very different from the Hoosac, where the grade being in both directions 26 feet per mile, a similar line would come out 35 or 40 feet *above* the top of the arch at both entrances. I may remark in passing, that there are frequent instances in European tunnels of a summit where the *track* in the centre is a few feet higher than the *track* at either entrance, but below the *roof*, whereas I have heard of no case similar to that at the Hoosac.

The rise from Modane is required for the ascent which is to be made by the line. The slight fall in the other direction is simply for purposes of drainage.

In section, the tunnel at Mont Cenis is 26 feet 3 inches wide, at the widest, and 20 feet 8 inches high above the rails. It is to be lined with masonry throughout, but no invert is required. The drainage is by a covered drain in the centre. Although all in rock, and some of it in very hard rock, the engineers are unwilling to depend upon this material without masonry; for as it is not homogeneous in character, there are parts which flake off, and in some places considerable masses have broken away during the construction. Of course they choose to take every possible precaution against accidents in a tunnel of such extraordinary length.

The masonry is of excellent character. The side walls are of stone, laid in regular courses, and on the Italian side the arches are of brick. The stone comes from neighboring quarries, that excavated from the tunnel being too rough and too much broken up, and at Bardonnèche the bricks are made upon lands belonging to the establishment, under the direction of the engineers. Recesses, sufficient for several men to stand in, are built in the masonry at the distance of 100 metres apart on each side, making one for every 50 metres, or 55 yards of tunnel; and once in every 550 yards a small side chamber is also built 10 or 12 feet square, which may be used as a storehouse for tools or materials. The thickness of the masonry for sides and arches is by rule 0.60 metre, or very nearly 2 feet, but this is varied somewhat to adapt the masonry to the roughness of the excavation, and it is occasionally increased where there is any unusual weakness in the rock.

The tunnel, of course, can have no shafts. At the summit of the mountain its depth below the surface is almost exactly one mile. Where the work is now progressing it was said to be from 1,500 to 1,800 feet below the surface. The accompanying drawings [PLATES XVI., XVII., XVIII.] exhibit its transverse section, and the plan and profile of the line.

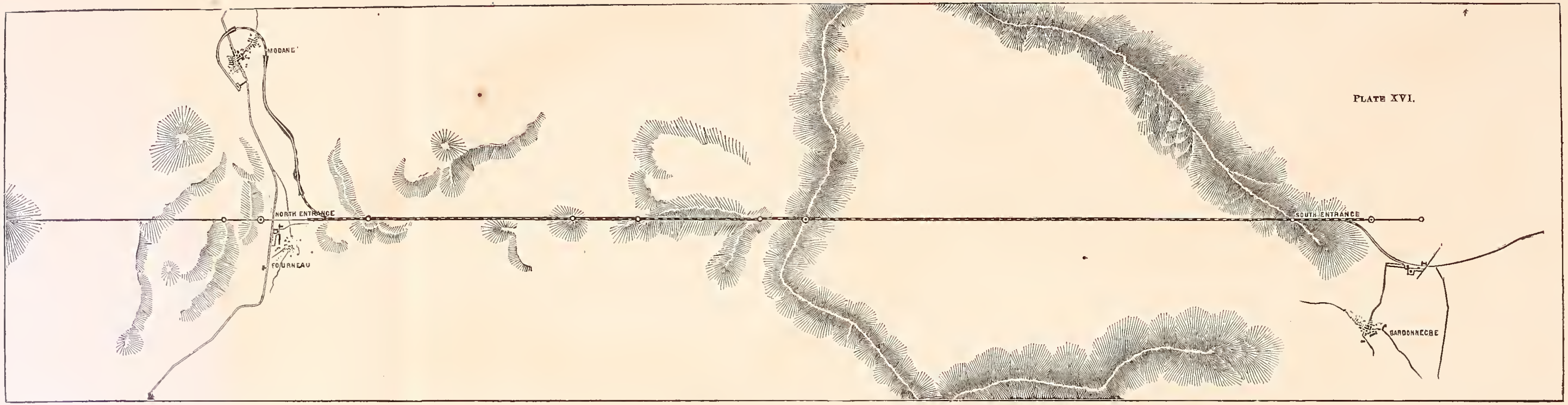
To lay out the line was no easy matter. Its length was determined by triangulation, the maps for which were shown to me at Bardonnèche. One base was measured by the engineers, and another taken from the system of government surveys with which theirs was connected. Fortunately they have been able to establish an observatory on the highest summit, from which they can see in each direction observatories placed at some distance from, and opposite each mouth of the tunnel. These observatories are stone structures, built with all the care necessary to insure the perfect stability of the instruments, and no apprehensions seemed to be felt as to the possibility of keeping the lines correctly.

Two important questions presented themselves at the very first suggestion of the project of tunnelling the Alps, and if they could not be satisfactorily answered, the attempt at such an unprecedented work ought not to be made. These related, of course, to its *ventilation*, and the *time required* for its completion.

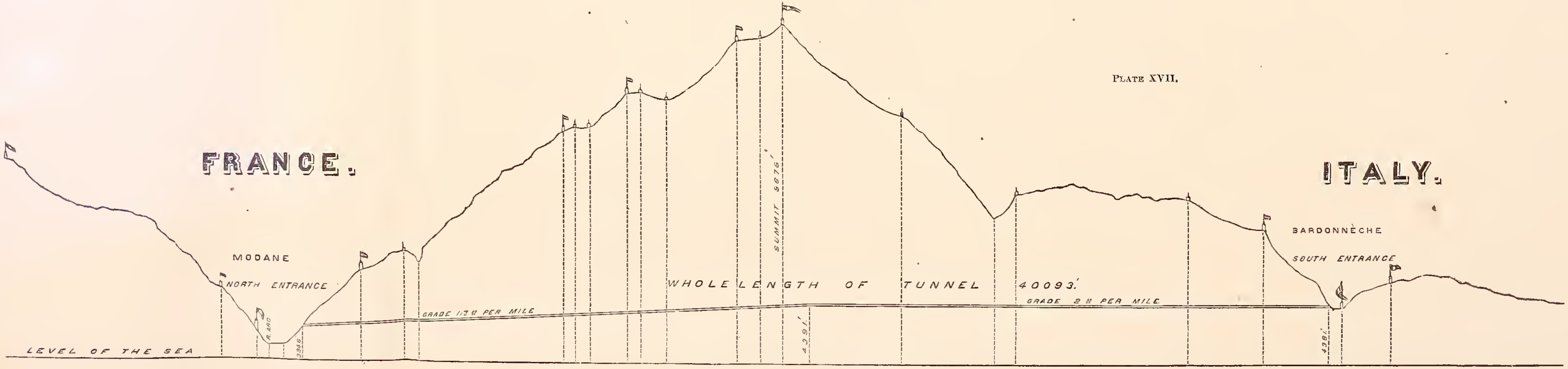
The tunnel, as has been stated, is necessarily without shafts, and it is between two and three times as long as any railway tunnel yet constructed. Without shafts, the work can only be carried on from the two end faces, instead of the numerous faces which the use of shafts commonly furnishes. Without shafts, the whole ventilation necessary to enable the workmen to pursue their labors must be furnished from the ends alone, and from a distance of nearly 4 miles. Unless means more powerful than those hitherto employed to supply fresh air, and means more rapid for driving forward the work at the only two available faces could be devised, the project would be absolutely impracticable, or from the great length of time required would be virtually so. It is by a novel use of compressed air that the engineers have undertaken to meet these difficulties.

The general principle is very simple, and may be stated in few words. The application requires a description of many details, and will be given hereafter.

The principle is this: Air compressed to a high degree may be driven through pipes of great length, and emitted at the place where it is needed for ventilation. Of course, when emitted under a high

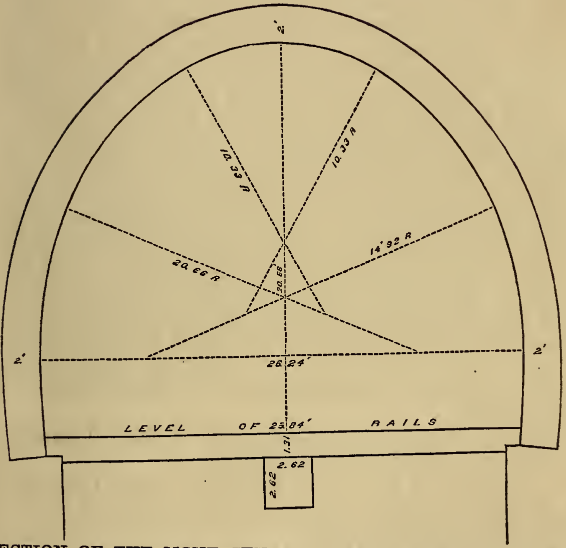


PLAN OF MONT CENIS TUNNEL



PROFILE OF MONT CENIS TUNNEL

PLATE XVIII.



SECTION OF THE MONT CENIS TUNNEL, UNDER THE ALPS.

degree of pressure, it exerts a force as it rushes out, and this force may be used to move machinery.

In a building erected outside of the tunnel atmospheric air is compressed to a pressure of six atmospheres, or about 90 pounds to the square inch, by the water power derived from a mountain stream. From the receivers which contain it, it is conveyed in iron pipes into the interior of the tunnel. It may there be freely let out at the needed point; it expands instantly to its natural condition, and furnishes pure air for breathing. It may also be ejected with the force due to its pressure, and acting mechanically it will drive noxious vapors before it. It may also be admitted against a piston moving in a tight cylinder, precisely as steam is admitted against a piston in a steam engine; and after having exerted mechanically its expansive force, precisely like steam, it escapes into the surrounding atmosphere precisely like exhaust steam, but instead of coming out a useless or hurtful vapor, its expansion, as it passes out from its condition of high pressure, absorbs heat and cools the atmosphere with which it is in contact; it comes out pure air fit for breathing; it can move the lungs of human beings after it has spent its force upon the inanimate machinery; and this machinery can be substituted for hand labor in drilling the rock through which the tunnel passes, and far exceed it in rapidity. Here, then, we have in compressed air the material to feed the lungs, to cool the atmosphere, to drive away vapors or natural exhalations, and to move time-saving machinery, the whole being furnished by water power outside of the tunnel, and conveyed in iron pipes, which may be of any required length, to the points where it is to be applied.

However ingenious this idea, yet for want of means of applying it in practice it might lead to no useful result.

A description of the works of Bardonnèche, which I first visited, will explain more fully the manner in which the engineers have undertaken to accomplish all this.

The works may be considered in three separate divisions. First, the receivers to hold the compressed air. Second, the machinery to compress the air and supply the receivers. Third, the drilling machines which the compressed air is to set in motion.

First. The receivers are iron cylinders with spherical ends, and made of boiler plate. There are ten of these at Bardonnèche, set up in two groups of five each, all communicating with each other so as to make virtually but one, and the aggregate capacity of the whole is 170 cubic metres, or 600 cubic feet. They are erected in a large

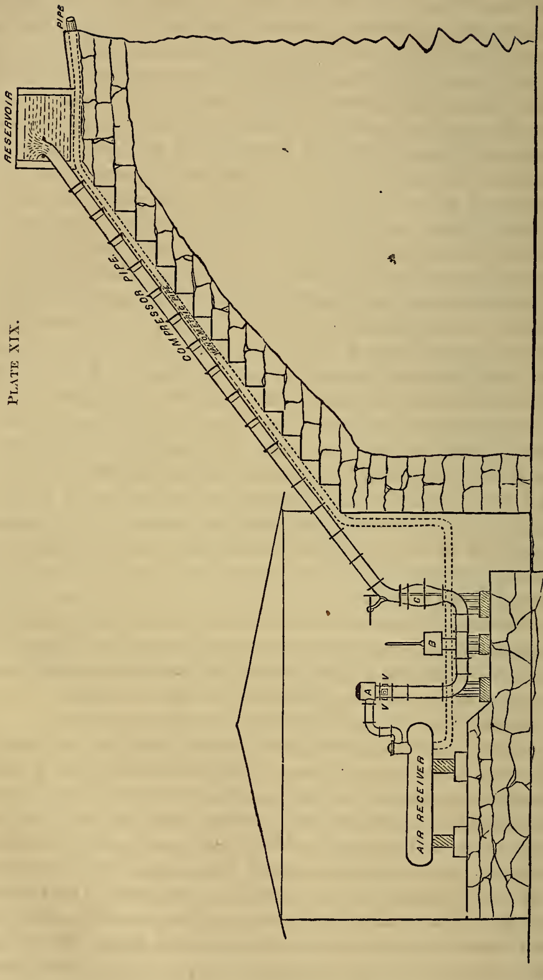
building standing about half a mile from the mouth of the tunnel. On the hill side, at the height of about 50 metres, or 164 feet above the receivers, is a reservoir of water with a surface of over 3,000 square feet, supplied by pipes laid from a small but permanent stream. By means of a constant influx, and ample means for overflow, the surface of this basin is kept permanently at the same level. From this, two iron pipes, which are called the manometric pipes, each 0.30 metre, or about one foot in diameter, are brought down to the two groups of receivers, with each of which one of them freely communicates. The air enclosed in the receivers, which at first was in its ordinary atmospheric condition, is, therefore, constantly pressed by the weight of a column of water 164 feet in height, acting directly against it, which is equivalent to about five effective atmospheres, and it will, of course, be condensed until its pressure exactly counterbalances that of the column. If a portion of the air in the receivers is now drawn out for use, the water descends by the pipes to supply its place, and maintains what remains in them at its original pressure. If air, on the other hand, is forced into the receivers, it expels an equivalent amount of water, which is thus thrown back into the upper basin, and the pressure remains precisely as before. The water let down in the first case is instantly supplied by the influx into the basin, and that thrown up in the second is instantly discharged at the overflow, so that the surface of the basin remains uniform, the column of water pressing against the air in the receivers is constantly of the same height, and the air constantly remains at the same pressure; that is, at a pressure due to 164 feet of water.

Glass tubes connected with the receivers show on the outside the height at which the water stands on the inside, so that the supply of air furnished to them may be increased or diminished according as a greater or less quantity is drawn out for use upon the works.

Second. Means for compressing air to supply the receivers.

At Bardonnèche this is done by *compressors* worked by water power. The water comes from a well-built stone dam erected across a small stream, from which it is conveyed a distance of nearly two miles to the compressors, by a canal lined with masonry, about four feet wide and three and a half feet deep, in which it stands at the depth of 24 to 27 inches. This canal has a constant but not a uniform slope, which must be considerable, as the velocity is very great. The water is opaque, turbid, and like all the waters of this region, discolored by the calcareous rocks and earths through which it passes. In order to clear it from sediment and other impurities, it is first admitted into a

PLATE XIX.



SECTION SHOWING MODE OF COMPRESSING AIR.

large basin, with a surface of 16,000 square feet, and a depth of five feet, where it loses of course its velocity, deposits what it has in suspension, and passes out again by a grated opening, the bottom of which is 27 inches below the surface. From there it continues again its course, by the canal, to a second and smaller basin near the works. From there again it passes through a double set of wire gratings into a third basin, standing at the height of 45 metres, or 147 feet above the receivers. All these precautions are necessary to secure water free from impurities, or foreign substances, which might be very injurious to the stop-cocks or valves through which it afterwards has to pass. In the granitic regions of New England, the clear water of our mountain streams would need nothing like this. From this third basin the water is let down by two iron pipes, each 0.50 metre, or 20 inches in diameter, to a reservoir built in masonry, forming the upper or second story of a building erected for the purpose, where it stands at the level of 25 metres, or 82 feet above the receivers, and close to the building which contains them; and it is from this last reservoir that it is let directly on to the compressors. The object of the whole work thus far, therefore, is simply to supply water to a reservoir 82 feet in height above the point where the water is to be used. The long distance from which it is brought, the deposit basins on the line, the height of 147 feet at which the third basin is situated, all these were peculiarities indicated or required by local necessities, resulting from the rough topography of the region, or the peculiar character of its water.

Between this reservoir and the air receivers placed in the building just below it, are the ten *compressors*. These are ten iron pipes, all precisely alike, which are in free communication with the water in the reservoir, and descend from it at an angle of about 45 degrees. They rest upon solid masonry built upon the side-hill, and enter the building in which the ten receivers are erected. Each pipe as it enters the building is turned vertically downward, as shown in the annexed sketch, and after a short horizontal course rises again vertically, and is then placed in communication with the upper part of the receiver, to which it corresponds. In the vertical branch near the receiver at A [PLATE XIX.] is a valve opening inward to the receiver, and which, though pressed on one side by the water held in the compressor pipe, tending to open it, is pressed on the other by the confined air, which has the force of a column of water twice as high held in the manometric pipe, and therefore keeps it tightly closed. Directly under the valve A are four small valves, v, in the side of the pipe, by which outward air

may be admitted, but opening inward to the pipe they are, of course, kept closed by the pressure of the water within it. On the horizontal branch is an escape cock, B, by opening which the water may be let out of the pipe. On the other side, at C, is a cock by which the communication with the reservoir may be shut off at pleasure.

We have thus an iron pipe full of water, descending from the reservoir with which it freely communicates, and holding water with a pressure of 82 feet against one side of a valve A, opening into the receivers, which is held down on the other side by air exerting a pressure equivalent to 164 feet. We now close the cock C, and thus shut off the water in its descent from the reservoir. We open the escape cock B, and the water below the valve A, in the branch next to the receivers will descend and escape until it reaches the level of the cock B, which may then be closed, and the air will enter by the four small valves v, and supply its place. The pipe will then contain a small column of ordinary atmospheric air in its vertical branch directly under the valve A, and the rest of the pipe remain filled with water. If we now suddenly open the stop cock C, which holds back the water of the reservoir, that water exerts its pressure, instantly acquires motion, and drives the small column of air, which the pipe contains, violently against the valve A, by its *shock* exerts against it a force much greater than that due simply to its pressure, compresses it sufficiently to throw open the valve, and injects it into the receiver. The reservoir is now again shut off by closing the cock C, the escape cock is opened, and another column or charge of air introduced into the pipe by the valves v; the escape cock is shut — the reservoir is again let on — the water ram again produces its effect, a second charge is injected into the receiver; and thus the process is repeated.

The foregoing description, imperfect as it is and must be, without drawings in detail, may yet serve to give a general idea of these compressors. Their action is intermittent like that of a water ram, exerting for an instant a pressure full twice as great as that due to the column of water which they contain, and at each stroke injecting a certain volume of compressed air into the receivers. The precise height of the valve A, above the escape cock B, which of course gives the height of the column of air which at every blow is to be compressed and injected into the receivers, was accurately determined by Mr. Sommeiller, by calculation and by experiment, so that exactly the whole of it should be driven through the valve by the shock of the water. The form of the stop cock C, was also contrived in such a manner that when opened it should form the least possible obstacle to the sudden press-

ure and motion of the column above it. And by an ingenious combination of cams and levers, the cocks B and C are opened and shut precisely at the proper instants. The power to move them for the 10 compressors is furnished by two small engines erected in the building, which are in every respect steam engines, except that *compressed air* from the receivers is admitted into their cylinders and drives the pistons, precisely as steam from steam boilers might have been admitted. They operate with perfect regularity, and this is very necessary, otherwise the pipes themselves would be exposed to the shock which, transmitted to the column of air which it is to inject, spends its violence in compressing it, and is checked by its elasticity. In a report, made by Mr. Noblemaire to the company now constructing the line of railroads in the north of Spain, which was published in the *Mémoires de la Société des Ingenieurs Civils*, in France, in June, 1861, which I have brought for the use of the Commissioners, is a description of these compressors, with drawings. Much fuller drawings, and on a much larger scale, being copies of those in his office, were kindly intrusted to me by Mr. Sommeiller, but with the confidence that they should not be used for publication, as it is his intention to present them to the public, with his own descriptions, as soon as he can find the leisure to prepare them to his satisfaction. I can, therefore, only offer them to the inspection of the Commissioners, without annexing them to this report.

I will further remark, in this connection, that these compressors are now rather a matter of scientific interest than of practical use; for although they are now, and have been for a long time, in operation, and in successful operation, at Bardonnèche, yet another system has just been introduced at Modane, the invention likewise of Mr. Sommeiller, which I believe to be far superior for the same purpose, and destined to supersede them wherever the locality will admit of its application.

Third. The Drilling Machines. These are small tools, weighing 300 or 400 lbs. apiece, occupying a space of only 6 or 8 inches square in section, and about 8 feet in length. They are placed in a horizontal position upon an iron frame or carriage, holding 9 of them at a time. The carriage is run forward and back upon a railway track in the centre of the tunnel, brings them up to the face of the rock where they are to be set in operation, and withdraws them when the rock is to be blasted. They are neither cutters nor excavators, but simply tools to drill holes, and the holes when drilled are blasted in the usual manner. Between two long parallel bars, about 4 inches apart,

lies an air cylinder $2\frac{1}{2}$ inches in diameter and 8 inches in length, made and used precisely like the cylinder of a miniature steam engine. In this cylinder runs a piston, moving horizontally forwards and backwards, and set in motion by *compressed air*, introduced by means of a flexible india rubber tube from the large pipes, by which it is conveyed along the floor of the tunnel from the receivers. The piston rod passes through the heads of the cylinder, and upon the forward end of it is fixed the drill, which thus becomes a part of it, and is driven forward and backward at every stroke of the piston. The slides which admit and shut off the air to drive this piston (precisely as steam is admitted to the cylinder of a steam engine), are themselves worked by cams connected with *another* and distinct air cylinder, also $2\frac{1}{2}$ inches in diameter, with a four-inch stroke, placed in the rear of the one first mentioned, and into which compressed air is introduced in the same manner. The piston in this second cylinder works with a uniform stroke and with perfect regularity. The length of stroke of the piston in the first cylinder is of course irregular, because the drill, fixed firmly upon the end of its rod, will advance more or less, according to the varying resistance of the rock against which it strikes, and to the progress it makes as it penetrates into it. It is for this reason that it cannot work the slides, and that the second or independent cylinder is introduced for that purpose. There is an ingenious screw arrangement, worked from the same cylinder, by means of which a rotatory motion is given to the piston which drives the drill, so that its position is slightly changed at every stroke, making a complete revolution in sixteen. By similar means a "feed motion" is given to the whole system of cylinder and piston and drill, causing them to slide forward between the two parallel side bars as the drill penetrates the rock, and to follow up the drill hole as fast as it is deepened. The carriage upon which the drills are placed, being chocked upon the rails upon which it runs, is the fixed point from which the advance is made. The machine, therefore, may be described in a few words as a diminutive air engine, the piston of which drives an ordinary drill, and a second air engine, which regulates the admission of air to the first one, gives a rotatory motion to the drill, and a feed motion to the whole tool.

In the foregoing account of the receivers, the compressors, and the drilling machines, I have aimed only to give a general idea of what they are, and have by no means undertaken to furnish a full description, by means of which they might be reproduced. The drilling machines, to be exhibited with all their ingenious details, would require

very elaborate drawings, and perhaps patterns. But they are quite small, easily transported, and can be procured through the assistance of Mr. Sommeiller, if it should be thought desirable by the Commissioners. The only printed account I have been able to find, is the report of Mr. Noblemaire, above referred to, which is dated June, 1861, since which date some improvements have been introduced, and additional experience gained by fifteen months' labor. Mr. Sommeiller, to whose inventive genius they are due, has thus far published nothing upon them, but he gave me a drawing on a scale of one fifth the full size, which shows the latest pattern. He frankly told me that the details had been gradually elaborated and perfected according to the suggestions furnished by practical use, that he had thus far considered them rather as in progress than as completed, and that he had been unwilling to give them to the public until he had first satisfied himself. For any one else to undertake to furnish complete and detailed drawings taken from the works in their present condition, would probably be to spend much time and trouble in describing some things already discarded or greatly improved. To undertake to do it from the drawings kindly furnished by Mr. Sommeiller himself, would be to deprive him of what he candidly told me he prized and claimed, that is, the privilege of introducing to the scientific world, in his own time and manner, as he hopes soon to do, the offspring of his own ingenuity.

Moreover, the object of my visit to Mont Cenis was to see results, rather than details; to see what progress was actually made, or whether, as I had heard in some quarters, the work was really about to be abandoned. I wished to see with my own eyes whether the machines in use were but an untried experiment, whether they were a proved failure and laid aside, or whether they were actually and uniformly at work, and how long they had been so. I wished to ascertain what confidence the engineers had in the success of their enterprise, and the reasons for that confidence if it existed; and, in fine, to see what could be learned, from the situation of this great work, useful to assist our judgment in relation to the feasibility, cost, or rate of progress of the work in contemplation at home.

While at Bardonnèche, I made several visits to the interior of the tunnel, and spent some hours within it, to ascertain from personal observation the state of the air at different places under different circumstances, and the manner in which the work was carried forward.

From the receivers which hold the compressed air, an iron pipe about eight inches in diameter is carried a distance of 930 yards to the entrance of the tunnel. This pipe is supported firmly at the height of eight or ten feet above the ground, on heavy bearings of masonry at very short distances apart. The lengths are bolted tightly together, the ends being ground or planed smooth to make good joints, and sliding joints being introduced sufficiently to allow the contraction and expansion resulting from changes of temperature. The pipe rests upon the supports, but is not confined to them. Where the pipe enters the tunnel, it is first secured against the side wall at the height of eight or ten feet from the ground, and it is so continued for some five hundred and fifty yards, after which it is let down and crosses to the centre of the road bed, and is there carried forward under ground, in the central drain between the two tracks. At the distance of 700 yards from the entrance, there stands in the centre, between the tracks, a little air engine of about two-horse power, which is literally nothing but a "steam" engine, in which the expansive force of compressed air takes the place of steam. The air is let into the cylinder by an india rubber tube, which takes it from the iron air pipe just below it. This miniature engine drives a fan, supplied with air from the central drain. The drain being large, and containing hardly any water, for the tunnel is perhaps more dry than any other I saw among all that I visited in Europe, serves very well for this distance as a conduit for fresh air. The fan drives this forward through a wooden box, from which it is emitted a long distance in advance. This seems to be a mere incidental appendage to the general system of ventilating. As the pipe on its passage could easily be tapped to supply power, which is let off or on by simply turning a cock, and, as the large dry drain offered a supply of good and cool air, it seemed natural enough to use the means thus ready at hand; and let it be remembered that the *power* used is *air*, and that as it escapes from the little cylinder at each stroke of the piston, it also ventilates the tunnel at the place where it issues. Upon looking at the cylinder while the engine was in operation, I saw that its outer surface was white as snow from the condensation of vapor upon it. The air coming out of the cylinder passes from the pressure of six atmospheres to that of one atmosphere, consequently it absorbs heat from every thing in contact with it, which is cooled in proportion, just as ice is formed by the evaporation of volatile liquids. I also noticed a little cloud, something like condensing steam, accompanying each discharge of exhaust air. This appeared to be the vapor held in the sur-

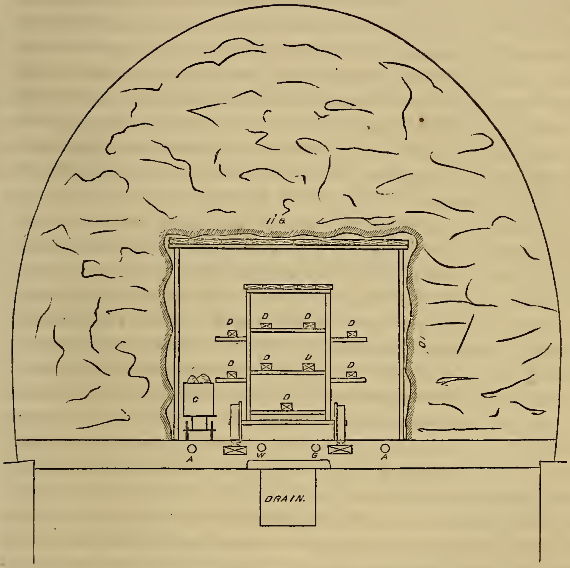
rounding atmosphere, condensed by parting with its heat to the expanding air. I have described this little engine thus minutely, because to the person who enters the tunnel for the first time it is a striking exemplification of the use of compressed air, the great instrument on which the engineers depend for the success of their undertaking. Very little air is used to drive these engines. It is cut off at about $\frac{4}{10}$ stroke, and works expansively for the remainder.

On the day of my first visit to the tunnel with Mr. Borelli, the resident chief engineer, the weather was exceedingly bad. It was raining very copiously, and the air outside was warm, close, and oppressive. On entering the tunnel, the air was sweet and clear, the sides and floor perfectly dry. On advancing, we heard repeated discharges in rapid succession. After entering some distance we passed through a cloud of vapors which resulted from the blasting we had heard, and were rolling towards the entrance. This was disagreeable, of course, but nothing more. Advancing further, the air grew better and better. We entered the heading or drift way, which is now about two hundred and seventy-five yards in advance of the enlargement, passed by the water tank and drill carriage, which had been rolled back upon the track to be out of the way of the discharges, and reached the end where the blasting had just taken place. We there found a large gang of men and boys actively engaged in clearing away the debris, picking down the loosened pieces from the face of the rock, loading them into narrow wagons and running them back past the drill carriage, out of the drift way, to the enlarged section where they were to be placed on cars of ordinary dimensions. The lights were all burning clear and bright, the air was perfectly good, the whole place light and comfortable, and full of people working with the greatest activity. The compressed air was heard escaping violently out of a nozzle in the pipe, precisely as water from the hose of a fire engine, and its mechanical pressure was readily felt by placing the hand in the neighborhood of the aperture. It is difficult to measure or define precisely what is comfortable or disagreeable. I can only say, that I am as sensitive to bad air as most people, but I know that I entered the tunnel with a violent headache and came out without one. Indeed, the place was then as good a place to work in as the entrance of the tunnel, and far better than many rooms often are in our factories. I was told that the physician employed by the government at Bardonnèche reports the sanitary condition of the men as entirely satisfactory.

At this visit, it will be observed that the drilling machines were not

at work, having been withdrawn from the face to allow of the blasting and removal of the materials. My next visit was made on the following day, a couple of hours after the blasting, that I might see them in full operation. On entering the tunnel we found, as before, but little vapor; afterwards passed through some clouds rolling slowly towards the entrance, emerged from them and reached the end of the enlarged section, where the small drift way or heading begins. The full section of the tunnel is 26 feet 3 inches wide, and 20 feet 8 inches high. The heading is carried forward about eleven and a half feet wide and nearly ten feet high. This is larger than the dimensions frequently given to these headings, but it is required in order to allow the drill carriage and its tender to be run in and out on a track of the ordinary gauge, and to allow space enough on each side of it for the passage of the little wagons used to remove the materials after the blast. It may be observed that the drilling machines *are used solely in the heading.* The whole of the enlargement is done by hand labor, in the ordinary way. The whole section excavated being about 645 square feet to a foot in length, 115 feet only, or about $\frac{18}{100}$ of the whole, is done by machinery. The primary object of this application of machinery is not to cheapen, but to expedite the work: not to save money, but to save time. This, of course, saves interest on great expenditures, and therefore indirectly saves money as well as time, but it is only by hastening the progress that it does so. The gauge or measure of progress, in this as in other tunnels, is the progress of the heading or first opening, where confined space limits the number of workmen. On the enlargement, a great number of men may find room to work, at the same time that the work is easier, so that no difficulty is found in keeping up with the rate of progress in the heading, whatever that may be. Advancing into the heading, we reached the drill carriage and its tender, in place, close against the face of the rock, and with its nine drilling machines at full work. The annexed sketch [PLATE XX.] shows a section of the drill carriage and the position of the machines. It is a simple frame of iron 8 or 10 feet in length, open on all sides, but covered with boards on top to prevent injury from any thing that might fall from the ceiling. Five machines, marked D, rest on the cross bars in its interior, four on projecting bars outside. They are simply secured by clamps and screws to these bars. The nine machines are all independent of each other. By loosening the clamps, they may be moved horizontally, simply by pushing them, and the cross bars can themselves slide up and down on the outer post of the frame. As each machine can thus have both a horizontal and a vertical

PLATE XX.



SECTION SHOWING DRILL CARRIAGE, AND POSITION OF MACHINES.

motion, of course the end of the drill can, within a certain range, take any desired position. In addition to this, it is evident that by sliding the rear end of the drilling machine horizontally to the right or left, while the front end is kept unmoved, the drill will take an oblique position, and a hole may be drilled obliquely to the face of the rock, if this should be desirable.

The drill carriage being brought up to the face, compressed air is admitted to each machine by a small india rubber tube, taking it from the two branch air pipes shown in the section at A and A. The large single pipe by which the air is conveyed into and along the tunnel, terminates in two small branch pipes, only 0.05, or two inches in diameter, which are carried along on the ground next to the sides of the heading, and as the enlargement proceeds, the full sized pipe is from time to time extended, and the branches moved forward again to its extremity. The drill of the proper size and shape is affixed to the forward end of the piston. One man stands by it to adjust and guide its first movement. Another tends the machine, and others are at work oiling the bearings, tending the lamps, or in readiness to move the machines, hand out the new drills, regulate the discharge of water, &c. Directly behind the drill carriage, on the same track, is the tank or tender already mentioned. This is simply a horizontal cylinder of boiler plate, with spherical ends, standing on wheels, by which it runs upon the track, and filled with water. The tunnel is so dry that it does not even afford water enough to fill this tender. The water is therefore introduced into the tunnel by a small pipe, taking it from a stream near the entrance. After the tank is partly filled and closed, recourse is again had to the universal agent, the compressed air. This is connected by a flexible tube with the interior of the tank, compresses the air in it to five effective atmospheres, is then shut off, and the tank is ready to eject water under that pressure. While the drills are hammering away at the rate of some two hundred strokes a minute, a fine stream or thread of water is ejected from the tank through a very small pipe, directly into the hole. This water, of course, under its pressure of five atmospheres, strikes with such force as to completely wash out the dust and particles of stone, as they are crushed under the drill. It also cools the drill and preserves its temper. Its action is therefore very important.

As I have said, the 9 machines were at full work. Fixed gas lights and movable oil lamps completely lighted the place, and were burning with perfect clearness. At the 9 drills and machines, and in and about the carriage, were some 30 persons. I stood at the front of the

machines, within three or four feet of the face of the work, and remained there, watching them, for perhaps three quarters of an hour. One drill was driving directly into hard quartz, advancing very slowly, and making the sparks fly at every stroke. Others, working in softer spots, were cutting rapidly. Some drills were blunted. Their single machine was stopped for a moment, another handed to the man at the face, who placed it in position, and the machine was started again, without interfering with the others. Some machines were stopped, then raised or lowered, to begin a hole in a new place. Every man seemed earnest at his work, and to work with ease. The exhaust air made the place as comfortable for respiration, and as cool, as ordinary factory rooms; vastly better than many factory rooms that I have been into. The only annoyance was the noise. It was precisely like the noise of the looms in the weaving room of a cotton factory worked at high speed. It required the same effort to make the voice heard, and shutting my eyes to listen to it, the illusion was perfect. The workmen seemed crowded. It may be that the presence of four or five spectators contributed to this. They were in front and behind, perched on both sides and inside of the frame of the drill carriage, like birds in a cage. I thought them in danger of being jammed between the machines, but the engineer said he had never known it to happen.

On returning out of the tunnel, we overtook nearer the entrance the vapors we had met as we came in. But they had so diffused themselves in the enlarged section as not to be much noticed. At the time of this visit, there were from 80 to 100 men at work enlarging the section, in addition to the 30 in the heading.

The machines, when brought up to the work, drill 80 holes before any blasting is done. Three of these, near the centre, are large, being about 8 centimetres, or rather more than 3 inches in diameter, and are not used for blasting, but simply as an "excavation" on a small scale, to facilitate the effect of the first blasts. The annexed sketch shows the position of the holes, and also shows by the figures, 1, 2, 3, 4, the order in which the 4 groups, into which they are divided, are successively blasted. As soon as the holes are all made, the drill carriage and the tender are run back upon the track far enough to be out of harm's way, and protected by doors or barricades. All the holes are then loaded, except the 4th group at the bottom. Group 1 is fired; then group 2; then group 3. The lower group, 4, is then cleared of the rubbish which falls upon it from the previous blasts, is loaded and fired. The air is then let out against the face,

drives back the vapors, and makes the place immediately fit for work to be resumed. Boys and men at once run forward to clear out the fragments or loosened materials. On each side of the heading is a track, of about a foot gauge, on which run little trucks, with wheels eight or nine inches in diameter. These trucks carry skips or wagon bodies, 4 feet long and 18 inches wide. The small fragments are hastily thrown into baskets, and emptied into these wagons. Larger pieces are lifted into them. As soon as a train of 4 or 5 wagons is loaded, it is run back upon the track, has just room to pass by the side of the drill carriage and tender, and reach the enlarged section, where large platform cars are standing in readiness. By means of a windlass and a rope and hook descending from the roof, the wagon bodies are lifted and placed upon the cars. It is intended, however, in future, to arrange for emptying them into the large cars, instead of carrying them out bodily. As soon as the materials are thus sufficiently cleared, the track is prepared, and the drill carriage and tender are run up again to the face. [PLATE XXI.]

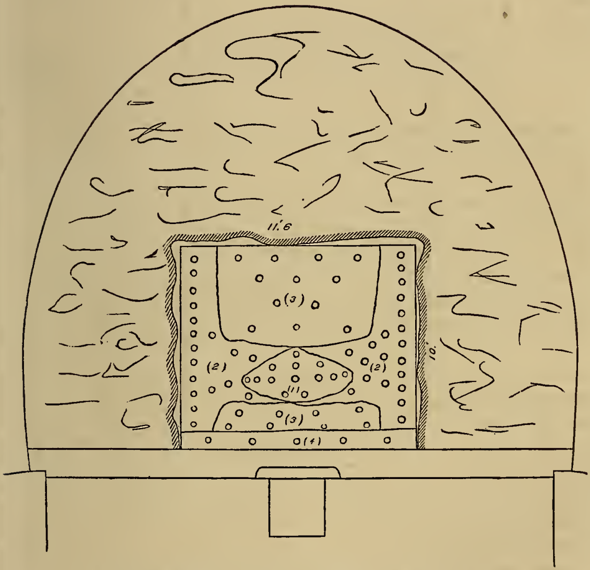
The rock has so many seams that it is unsafe to trust it long unsupported. In the heading, where so much room is required for the machines and the men, ordinary wooden props, of the requisite strength, would occupy too much space. The vertical supports are, therefore, of iron, about $2\frac{1}{2}$ inches square, and for the horizontal bars resting upon them to support the ceiling, old rails are used. Behind and above these, planks are placed in the usual way. Mr. Borelli, the resident chief engineer at Bardonnèche, told me that he had found great advantage in the use of iron instead of wood, so much so, that he was inclined to recommend it for tunnels generally. Thus far, however, it has only been used in the heading, the propping elsewhere being timber as usual.

The holes drilled by the machines are from 32 to 36 inches in depth. For the 3 large holes, which are not blasted, a drill is used which has a diameter of about $1\frac{1}{2}$ inches for a length of 4 inches, and is then enlarged to a cutting shoulder about 3 inches in diameter, as shown in the annexed sketch. If the rock is very hard, drills about $\frac{1}{4}$ inch smaller are used. [PLATE XXII.]

For the other holes, drills are used of 3 sizes: Nos. 1, 2, and 3, which are respectively of the diameter of $1\frac{9}{16}$, $1\frac{7}{16}$, $1\frac{5}{16}$ inches; the smallest being used for the hardest rock.

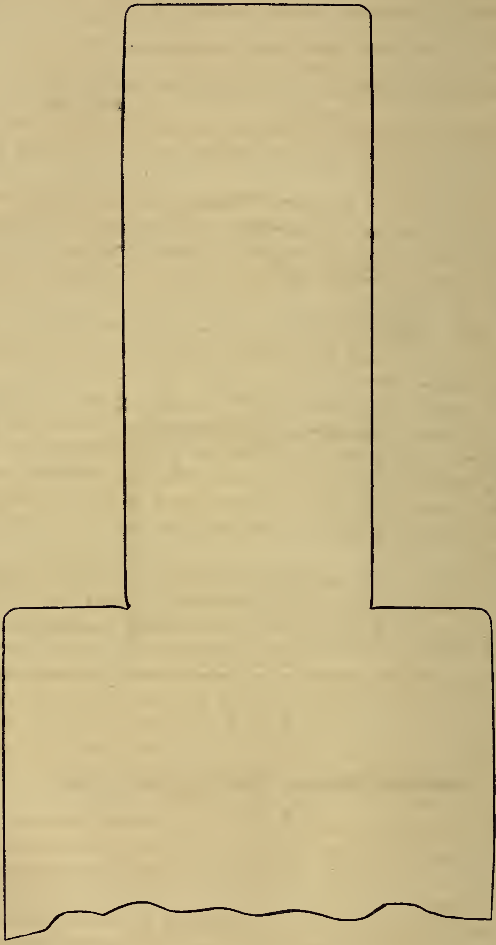
Where a particularly hard rock is met with, they sometimes begin with a large drill, No. 1, and successively use smaller drills, Nos. 2 and 3, as they deepen the hole.

PLATE XXI.



SECTION SHOWING POSITION OF BLASTS.

PLATE XXII.



LONGITUDINAL SECTION OF LARGE DRILL.

To make 80 holes, they generally use 120 drills, but sometimes one drill will make 2 or 3 holes, and sometimes one hole will require 2 or 3 drills. The common section of the cutter at the end of the drill is . If the rock were more homogeneous they would use a straight edged cutter . The greatest difficulty encountered is the want of homogeneity, which they consider much worse than hardness. The Z section, with the rotatory motion of the drill, partly obviates the difficulty.

Little cylinders of clay, about 6 inches long, pressed to their shape in a die, are made in large quantities near the mouth of the tunnel, and are used as wadding in loading the holes for blasting.

Mr. Borelli gave me the following account of the manner in which the labor is organized : —

Sunday is unknown under the Alps. There are six great yearly festivals ; and leaving out these, the work goes on, uninterruptedly, 359 days in a year.

The masons' work is carried on 8 hours per day, and by the same men of course every day. This suffices to keep the masonry up with the rest of the work, and there is no change of gang.

The excavation for the enlargement of the tunnel to its full size is carried on 24 hours per day, by 3 separate gangs, each working 8 hours, and each having its proportion of miners, strikers, and other laborers.

The drill carriage is brought up to the face twice a day, and set to work. The 80 holes are drilled in from 5 to 7 hours ; they are then loaded, blasted, and the debris removed, ready for the machines to act again. This operation is effected twice a day.

The machines require 30 men at once to work the whole 9. One stands at the drill ; another, near the front of the machine, changes the drills, moves the machine when necessary, either up or down or sideways, to the place for new holes ; a third, inside the frame of the drill carriage, directs the admission of the air ; and 2 or 3 more oil up, look after the lights, and assist generally.

All these men are changed twice a day, making therefore 2 gangs of 30 each. Of course it will be seen that they do not work 12 hours, but only during the time the machines are working for a single turn.

There are 6 men and 2 boys employed in loading the holes for blasting. They go to work twice a day, after each set of holes has

been completed. As their work is light, and not of long duration, the same gang comes twice a day into the tunnel for this work.

There are 20 men and boys employed to remove the debris after each blasting. Their work is not long, and the same gang comes twice a day into the tunnel for the purpose.

Thus we have for a day's work at the heading,

60 men (2 gangs of 30)	. . .	at the machines.
8 men and boys	. . . .	to load and blast.
20 men and boys	. . . .	to remove the debris.
—		
88 workmen.		

These men are not equally paid. The prices range from 1.50 francs per day for boys, to 5.50 for the best mechanics. The men who blast have 4 francs per day. Mr. Borelli thought the average price of the whole would be about 3.50 francs, or 70 cents per day.

It is a great object to induce these men to work as expeditiously as possible. In order to encourage them to do so, premiums are paid for extra speed. It has been stated that to drill the holes requires from 5 to 7 hours. If the gang at the machines can complete the holes in less than 6 hours, they all receive as a gratuity $\frac{1}{4}$ of a day's wages. That is, they receive pay for $1\frac{1}{4}$ days instead of 1 day. If the work is completed in less than 5 hours, they all receive $1\frac{1}{2}$ day's wages. This has been accomplished, but it is a very rare occurrence. Energetic and rapid work, therefore, insures them fewer hours of labor and more pay. The completion of the task is the work for the day. At first a premium was paid on the advance of *each machine.* It was found that the men interfered with each other, every one driving his own machine, and, if need be, to the inconvenience of his neighbor. Now the premium is for the whole gang. Therefore, every one is interested, not to hinder, but to assist his neighbor; and if an indolent or careless workman is among them, his companions soon find him out. There is a similar system of premiums for extra rapidity in removing the materials after blasting; but there is none for the men who blast. Their labor is not of long duration, and they are well paid. For them, a premium on speed would lead to haste, carelessness, and accident. As so much depends on the skill, assiduity, and coöperation of the workmen, this system of premiums seems to be very wisely adopted.

Mr. Borelli stated that up to January, 1861, the whole work of the tunnel had been done exclusively by hand labor. Since then, up to the present time, the whole work in the heading has been done exclu-

sively by the machines, the enlargement being executed by hand labor as before. At the time of my visit, in September, 1862, they had therefore been at work about 19 months. The whole distance from the entrance to the place where the machines are working is now (Sept. 6, 1862) 1,160 metres, or 1,268 yards. The monthly advance made by hand was 20.52 metres, or $22\frac{1}{3}$ yards on the average. The monthly advance now made by the machines is about double. With occasional variations, the rock has been in general the same from first to last. I have brought home, for the examination of the Commissioners, a number of specimens which are a fair sample of its quality, and seem to me as hard as the Hoosac rock. The engineers are by no means satisfied with the progress they make. While it is already double that made by hand, they hope to increase it to threefold or more. They now count on 40 metres, or about 130 feet advance per month at one face; their aim is to reach 70 or 75. In questioning them as to the particular points where improvements are to be expected, I find them to be, in the first place, such an organization of their labor as to make 3 turns a day, instead of 2, with the machines. This alone would add 50 per cent. to their advance. And it seemed to me not at all unlikely to be effected. Besides this, they expect that experience will indicate, as it has already done, further improvements in the details of their machines; the best size and weight for them, the best pressure at which to use the air, the best size for the drills, the best form for the cutter at the end, the speed at which the machines shall be driven, the proper conveniences for quickly adjusting and moving the machines and drills. The skill and ingenuity already displayed can hardly fail, when assisted by experience, to produce improvements in these particulars. And all these improvements in work and details are fortunately of such a character that they may be introduced without at all delaying or interfering with the good results already obtained. A new machine may be placed upon the drill carriage while it is drawn back from the work; a new drill may be placed at the front of any machine; a new drill carriage of different construction, all loaded with its drills, may be run into the tunnel and substituted for the old one without delaying its advance to the front at the proper moment.

The best evidence of the results thus far produced is given by the following table of the monthly advance from the beginning of the work up to the present time. The opening was commenced in October, 1857; and on the 30th November, the distance from the entrance to the head of the drift way was 9.50 metres. Since then the monthly progress has been as follows:—

Monthly progress by hand labor.

	Distance excavated. Metres.
1857, November 30,	9.50
December,	17.78
1858, January,	23.72
February,	20.00
March,	21.77
April,	21.23
May,	24.00
June,	21.00
July,	23.94
August,	22.26
September,	20.53
October,	18.49
November,	20.36
December,	20.27
1859, January,	24.15
February,	20.20
March,	20.95
April,	10.15
May,	18.10
June,	11.70
July,	16.90
August,	15.40
September,	17.90
October,	21.55
November,	17.95
December,	20.40
1860, January,	8.05
February,	17.05
March,	23.45
April,	24.80
May,	25.50
June,	23.45
July,	21.72
August,	30.03
September 19th,	11.00
October, November, December, 1861, January 12,	18.75
	704.00

Monthly progress by machine labor.

	Metres.
1861, February, March,	9.50
April,	17.50
May, June,	13.71
July,	18.38
August,	24.14
September,	23.67
October,	25.65
November,	8.10
December,	31.00
1862, January,	32.50
February,	28.60
March,	34.75
April,	35.00
May,	35.20
June,	33.00
July,	39.00
August,	37.00
	446.70
Brought forward,	704.00
	1,150.70

On the 31st January, 1860, the heading had advanced to 523.25 metres from the entrance, the enlarged section having then been brought up to 508.25. A change was made in the manner of working at that date. Prior to this, the heading had been carried forward at the *top* of the section. It was now carried forward at the *bottom*. To make this change, the advance of the heading was slackened until the enlargement at the bottom reached it, and the new heading was carried forward. On the 29th February, 1860, the heading at the bottom was completed to 525.30 metres, and the monthly progress after that date is measured at the bottom.

The table shows an average progress of 20.52 metres, or 22⅓ yards per month, for 32 months, from December, 1857, to August, 1860, inclusive, during which period the work does not seem to have been interrupted. Indeed, Mr. Borelli told me that it was vigorously pressed forward. This was all done by hand labor in the usual way.

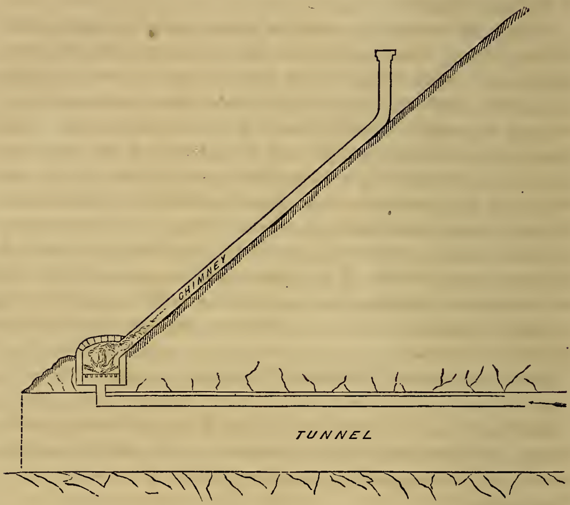
After September 19, 1860, there was a long interruption, to prepare for the machines, which were started January 12, 1861, and appear to have made but little progress until the first of July, when they were fairly at work. They worked steadily for the four months of July, August, September, and October, 1861, and made an average monthly progress of 22.96 metres, or 25 yards. This was but little better than hand work. In November, work was suspended 22 days for the purpose of making alterations in the drill carriage, the effect of which is immediately seen. For the next 9 months, and up to the present time, the work by machines has been carried on without interruption, and for these 9 months, the average monthly advance has been 34 metres, or 37 yards. In July it was nearly 43 yards. In some weeks, work has been done at the rate of from 44 to 48 yards per month, and a rate of progress by the machines in their present condition may be considered as already certain to the extent of double that by hand.

Nine months of uninterrupted daily labor, with such results, show that the feasibility of drilling by machinery is no longer a question. Improvement in its use is also manifest. The last months are the best. I consider the possibility of an advance double that by hand labor already demonstrated, and I have great confidence that a threefold advance will be attained at no distant day.

Before leaving Bardonnèche I will add a few more details to those already given.

There are 10 compressors, but they are not all kept at work. Eight of them working 14 hours out of the 24, and making 3 strokes

PLATE XXIII.



SECTION SHOWING CHIMNEY.

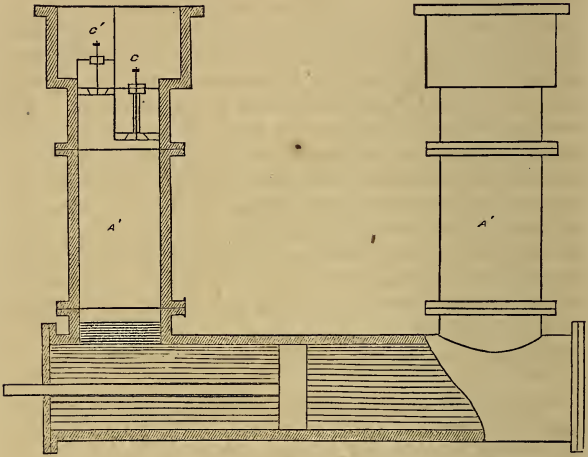
per minute, supply all the air that is needed at present. It should be stated also, that the water which is brought to the works is by no means all used, a large portion being let off and wasted, and that while the whole fall is 45 metres, only 25 are actually made available. It is evident, therefore, that means are at the disposal of the engineers for compressing a very much larger quantity of air whenever the progress of the tunnel may require it. The air receivers now have a capacity of 170 cubic metres. The intention is to increase it to 600 cubic metres, or 2,119 cubic yards, so that being kept in store, as it were, a large quantity of air may be drawn out without too much impairing the supply.

Besides the means of ventilation already described, an inclined chimney is now being constructed, with a section about 40 inches square, which starts from the inside of the tunnel, 20 or 30 feet from the entrance, runs up the slope of the mountain, rising nearly at an angle of 45 degrees, and terminates in a vertical summit. This chimney is to have a large fire-place at its foot, near the top of the tunnel, and the air is to be supplied from a tight wooden box, opening underneath the fire-grate, and from there extending a long distance into the tunnel, where it is suspended near the ceiling. The fire is to create a draft, and the air to feed it will thus come from the interior of the tunnel, near its roof. The chimney may be continued up the hill to an indefinite height, and it is expected that it will be very useful in clearing the tunnel of the vapors which the compressed air is driving out from the interior.

The annexed sketch [Plate XXIII.] shows its position.

At Modane, on the French side of Mont Cenis, the work upon the tunnel is less advanced than at Bardonnèche. The drilling machines are not yet in operation, and the compressed air is only used for the other purposes for which it is needed. The machines are already in the workshops, the drill carriage is prepared to run them in, and the resident engineers are only waiting the orders or the presence of Mr. Sommeiller, who was expected from day to day, to set them at work. The means here employed for compressing the air are quite different from those previously described. The water power is derived from a rapid mountain stream, the Arc, which runs through the narrow valley with a considerable quantity of water and but little fall. A slight obstruction placed in the channel throws the water into a canal about 20 feet wide, which conveys it a distance of some 275 yards to the wheels upon which it is to be delivered. These wheels are overshot

PLATE XXIV.



SECTION OF PUMP FOR COMPRESSING AIR.

wheels, with elbow-buckets. They are six in number, all alike, each of them 5.80 metres, or 19 feet in diameter, 4 metres, or 13 feet in length, and making about 8 revolutions per minute. They are erected in one line in a substantial stone building, which also contains the pumps which they are to drive. The water is introduced with considerable horizontal velocity at the top of the wheels.

Outside of the building, and very near it, are the compressors. The reservoir to supply them with water is not on the side hill, as at Bardonnèche, but is a large tank supported vertically in the open air at the height of 25 metres, or 82 feet above the ground, by a strong iron framework. From this tank the compressor pipes descend vertically, and then turn and enter the building which contains the air receivers, to which they are connected precisely as at Bardonnèche. There are 10 receivers and 10 compressors, with the same system of valves, and cocks, and air engines to move them, being duplicates of what has already been described. The water wheels were intended to raise water by pumps, so as to keep the tank or reservoir full, and thereby work the compressors. Subsequently, however, to the erection of these compressors, a different system for compressing the air has been invented by Mr. Sommeiller, and inevitably must supersede them. This consists in the use of a double-acting pump, in which the piston drives a column of water against a column of air, compresses it, and throws it into the receiver at each stroke. The annexed sketch [PLATE XXIV.] will serve to explain this. The pump is composed of a horizontal cylinder full of water, in which the piston moves, and two upright cylinders, A, A′, which contain alternately air and water. At the top of each upright cylinder are two valves, the lower one, C, which is kept covered with a little water, opens inward, and thereby admits air into the cylinder A. The other, C′, opens outward, and thereby allows air to escape from the cylinder. If the piston moves towards A, the water is driven up the cylinder, compresses the air, drives it out by the valve C′, into the chamber, whence it is conveyed to the receivers. As the piston moves back in the other direction, the valve C opens and admits air, which fills again the cylinder. The two upright cylinders are precisely alike, have similar valves, and act alternately at every stroke of the piston. The length of stroke and dimensions of the parts are so arranged that the whole of the air in the upright cylinder is ejected from it at each stroke, a very small quantity of water covering the valve C being allowed to enter with the air, and being again driven out by the valve C at the return stroke.

In this machine, as in the compressors, it will be noticed that the

air is compressed, not by a piston, but by a column of water acting directly against it. In the compressors the column acts by its weight and shock. In the pumps it acts under the impulse of the piston. This machine is simple, inexpensive, and effectual. The piston is driven by a rod directly connected with a crank on the shaft of the wheel. Each wheel runs two pistons, one from each end of its shaft; thus there are 12 double pumps for the 6 wheels. Each wheel at every revolution throws 4 cylinders of air. This would make, with 8 revolutions per minute, which the wheel was making when I saw it, 32 cylinders for each wheel, or 192 cylinders of air per minute, if all were in operation. At present only four pumps are completed. A single wheel, working a few hours per day, supplies all the air that is needed.

Here then, as at Bardonnèche, the engineers have at their disposal vastly greater means for compressing air than are yet employed. And the surplus power is even greater than at Bardonnèche. This may be a fortunate circumstance, because the tunnel *rises* rapidly from the Modane entrance, and it may eventually require more power to drive the noxious vapors down through the tunnel than to move them through the nearly level line at the other end. It may be seen by the figure that there are no means of readily getting at the piston, and that its surface may be worn by friction. Mr. Sommeiller has just completed the invention of a different arrangement for the horizontal cylinder and piston to be used for the pumps which remain to be set up. The principle is the same, and the improvement is merely an ingenious modification of details. His draughtsman, who accompanied me on my return to France, was on his way to Belgium for the purpose of having the new work executed.

The compressors at Modane have never been used; I believe they never will be. The great fall and small quantity of water at Bardonnèche led, in that locality, to the idea of using the column itself to compress the air. Its continued and successful use in that way naturally suggested the adoption of the same method at Modane, where the local circumstances were different; and the attempt was made, by pumping up water, to reproduce artificially what nature had supplied elsewhere. Pressed by public expectation, urged to do something, to satisfy in some way the public requirements, Mr. Sommeiller erected what he knew would answer. And if near its completion he contrived something much superior to it, he should not be censured for a useless expenditure upon the old, which has only been superseded through his own ingenuity in perfecting the new. If in the subsequent ar-

rangements for prosecuting his great work he should frequently modify and improve his own first conceptions, it may be a very good reason why others, not involved in such a stupendous undertaking, may hesitate to adopt his processes, but it is none why any less confidence should be felt in his ability and ultimate success.

The pressure in the receivers at Modane is kept up precisely in the same way as in those at Bardonnèche, by the weight of a column of water 164 feet in height, held in pipes communicating with them at one end, and at the other terminating in a reservoir or basin on a neighboring hill, where it is supplied from a very small stream, sufficient for this purpose.

From the receivers an iron pipe, precisely like that already described, and supported in like manner by posts of solid masonry, runs for a distance of 1,010 metres, or 1,100 yards, to the entrance of the tunnel, which is 105 metres, or 344 feet above the level of the pumps. The entrance is placed at this height to conform to the grade of the line, which rises very rapidly in the valley, or rather gorge, through which flows the Arc, and continues to rise in the tunnel at the rate of over 117 feet per mile for half its length, as has already been stated.

The pipe enters the tunnel and is supported along the side wall for some distance, after which it descends and crosses to the central drain, which it then follows to the end of the excavation.

The construction of the tunnel itself is precisely the same as at Bardonnèche, and it is unnecessary to repeat the description. The arch, however, is here of stone, as well as the sides. I went with Mr. Copello, the resident chief engineer, to the extreme end, which is now 880 metres from the entrance. The air was good, and there was no difficulty in working, although it was not long since blasting had taken place. There is blasting, he told me, as often as once in every two hours in some part of the work.

The rock differs in character from that at Bardonnèche, which is, in general, of a calcareous nature (*Calcaire schisteux*). The beds vary greatly, — some are almost anthracite, others are sandstone, and others are large masses of pure quartz; but the beds themselves are more homogeneous than on the other side. The rock in which they are now working they call *grès anthracifère* and *grès quartzeux*, the latter, especially, being very hard. They have passed through some anthracite nearly fit for combustion. This has proved very troublesome and dangerous, from its crumbling nature. Hereafter, they expect to deal with the harder material, and are prepared for it.*

* I have brought with me a number of specimens, for the examination of the Commissioners.

In the workshops, where the drilling machines now stand ready to be started, a very large block of stone, twice the size of a mill stone, is placed in front of them for trial. It is a quartzose rock, harder, they say, than any thing met with in the tunnel. Mr. Leandre Sommeiller, a brother of the engineer, here has charge of the workshops and machinery. He let on the air, and set a large drill in motion against the rock. In $6\frac{1}{2}$ minutes it entered 14 centimetres, or $5\frac{1}{2}$ inches. His own assertion was that they would make much better progress than that at the rock in the tunnel.

The average progress made by hand does not vary much from 20 metres, or 22 yards, per month; but as the strata have been very different in quality, there has been a great difference in the advance in different months. The engineers are confident that they shall double their progress as soon as the machines are started, and hope to do much more. They are now running forward the heading at bottom, as this is required by the machines. Formerly it was run forward at top, which Mr. Copello considers unquestionably the best method when working in rock by hand labor,—an opinion in which Mr. Borelli coincides.

What precedes will give some idea of the character of the enterprise, the difficulties to be overcome, the means employed, and the results obtained.

With Mr. Grattoni, I had, upon my arrival at Turin, a long and agreeable interview. With Mr. Sommeiller I spent many hours and many days in discussing the interesting points of his work. I had been told in England that I should find them rather wary, shy of criticism, and not ready to impart information. I found them exactly the reverse. Every inquiry was freely and readily answered, plans were exhibited, and full permission given to inspect personally any thing that I wished. Mr. Sommeiller, in particular, gave me a great deal of his time, furnished me with letters to Mr. Borelli, an engineer of great intelligence, who, with Mr. Carbillet, the superintendent of the mechanical department, has been attached to the works at Bardonnèche from the very outset; and also to Mr. Copello, the engineer, and Mr. Leandre Sommeiller, the mechanical superintendent at Modane. These gentlemen, as well as their principals, gave me much of their time and attention. Mr. Borelli, especially, at the request of Mr. Sommeiller, placed his drawings and his records in my hands; and all of them, instead of shunning, seemed to court inquiry, and to all of them my cordial acknowledgments are due.

For the construction of the tunnel, the great instrument in the hands of the engineers is compressed air. And what an instrument it is! By its aid they furnish *air* for respiration, *wind* to drive away vapors, *power* to run machines. They eject *water* to play against the rock, produce *cold* to temper the atmosphere, and *heat* by a blast at the forges near the entrance. Thus air, wind, power, water, cold, heat, can all be applied, and precisely where they are wanted. This sounds like fable, but it is a literal truth.

The means already at the disposal of the engineers for increasing the quantity of compressed air, and, if necessary, its pressure, far beyond what is now needed, give them entire confidence that its agency will be sufficient for any future requirements. It is now conveyed at each entrance a distance of about 2,000 metres, or a mile and a quarter, from the place where it is compressed. The loss of pressure is very trifling. It is emitted at the end of the pipes almost as it enters. They have no hesitation in asserting that they can use it at distances of 8 or 10 miles without any difficulty, and Mr. Sommeiller has made some experiments in confirmation of this opinion. It is indeed a wonderful instrument as they use it, and many other possible applications of its properties suggest themselves. To compress air does not create force, but transmits it. Power is wanted at long distances within the tunnel. The two ordinary motive powers are water and steam. The former must be used where it is; the latter, for most purposes, can be produced where it is wanted, but the accompanying heat and smoke, and the need of draft, render it impossible to produce it in the tunnel. Nor can it be transmitted in pipes from the outside without condensation. But air, compressed where the power is, can be transmitted to where the power is wanted. Not only to the very end of the tunnel, for the drilling machines, but to the forges, the workshops, or wherever else upon the whole premises its use may be of advantage. At the entrance of the tunnel at Bardonnèche is a blacksmith's shop for repairing tools, all the fires of which are blown from the pipe; and another building is in process of erection, in which air engines, supplied from the pipe, are to drive the tools and machinery. The engineers, indeed, look to its future application in large manufacturing establishments, where (as in print works) it is desirable that each machine, for the purpose of regular motion, should run independently of the rest. This may now be done to some extent by steam conveyed in pipes from a central boiler, but condensation limits the distance. If it were done by compressed

air, conveyed in pipes from a central receiver, the distance might be indefinitely increased.

They think, then, that they have in their hands means to ventilate the tunnel during its construction, and to drive the machinery required for its rapid progress. As regards ventilation after the tunnel shall have been completed, they have no fears, and do not expect to require the aid of artificial means. The completed railways on both sides of the tunnel, and with which it is to be connected, are single track railways. Yet they have insisted upon a tunnel large enough for a double track. Whether one or two tracks shall eventually be laid, they consider this section as the smallest that would answer for purposes of ventilation. They mainly depend upon a natural current of air, which they expect through it. Modane is a cold valley, on the north side of the mountain. Bardonnèche is a much warmer valley, on the south side. Mr. Grattoni told me, that observations which have been continued for three years, show that there is almost invariably a great difference in the temperature between the two, and also in the barometric heights. Taking also into consideration the prevailing direction of the winds, and the fact that the Bardonnèche end is 435 feet higher than the other, they see reason to expect an almost constant current from north to south, and indeed have thought it might sometimes be necessary to check its force by curtains across the entrance. Should, however, any future difficulty arise after the tunnel is in operation, compressed air may still be used as a ventilator; and indeed it would not be surprising if Mr. Sommeiller should, in case of need, examine the possibility of its use as a motive power within the tunnel, sufficient to obviate the use of steam in the transit through it. The idea has certainly suggested itself.

The railways on each side of the tunnel have but a single track. On the line from Turin to Susa, which is the last link in the chain of *Italian* railways, there are 6 passenger trains each way, three of which are merely local trains, and three convey passengers to cross the mountain. There is but one freight train. On the line from Culoz to St. Michel, the last link in the chain of *French* railways, there are three passenger trains and one freight train. The tracks through the tunnel are on the English gauge, 4 feet 8½ inches, and the cars at each end, both freight and passenger, all being 4-wheel cars, are of about the same size in cross section as those in use on our New England roads.

Mr. Sommeiller claims the compressors, air pumps, and drilling machines, as exclusively his own invention. He has patents in

Europe, but not in America. In December, 1856, and January, 1857, experiments were in progress, and were continued until June, 1857, when the whole system was exhibited to the government and to the public.

All the machinery and iron work, of all kinds, for both ends of the tunnel, comes from the shops of Mr. Cockerel, at Seraing, in Belgium. Mr. Sommeiller spent nearly two years there with his drawings, getting his ideas reduced to practice. Experiments and changes were constantly made, and a good deal of work proved useless. With no experience to guide him, he had to grope his way. The first drilling machine cost more than four times what they now cost. Latterly, he has paid 2,000 francs, or $400 apiece for them.

With his latest system of pumps for compressing air he is entirely satisfied, and looks for nothing further in that direction. The main mechanical improvement to be looked for now is in the details of the drilling machines and the arrangements of the drill carriage. How to conciliate strength with lightness and ease of adjustment, and in what proportions, if need be, to sacrifice one to the other, to obtain the best result on the whole, are the objects of his study. He has already doubled the rate of advance, but he confidently hopes to make it threefold.

He has never given his attention to large machines for excavating a full section at once — and he has no faith in them. The more portable the machines can be made, as his drilling machines are, the more useful he believes they will be found in practice.

The cost of the works at Mont Cenis it would be impossible to obtain in detail. Nor would the information be of any great practical value. The amount spent in experimenting upon a new invention has little to do with the value of the invention when completed and reduced to practice. The works have, unquestionably, been very costly. The whole sum expended at the time the convention was made with the French government was rated at 10,000,000 francs. The estimate then made for the progress of the tunnel was 3,000 francs per metre. But this is not enough. It will require 3,500 francs per metre, or $640 per running yard. 2,000 metres are now substantially done, and 10,000 metres remain to be done. The amount now expended is about 11,000,000 francs. To complete 10,000 metres will require, according to the latest estimate, 35,000,000 francs, making a total of 46,000,000 francs, or $9,200,000. If we suppose the 2,000 metres already done to have cost the estimate price

of 3,000 francs per metre, this would amount to 6,000,000 francs, and would leave 5,000,000 francs, or $1,000,000, as the cost of the works and experiments, independently of the cost of the tunnel. These figures are certainly alarming to those who might propose to adopt a similar system in places where the circumstances do not render it absolutely necessary, and where the work has not the treasury of two great nations to support it.

From all I saw and heard, I am confident that there is no economy in the use of machines, as far as regards the actual cost of the work done, independently of the time, and therefore of the interest on the expenditures. In a case like that at Mont Cenis, however, supported by the finances of France and Italy, a national work and not a commercial enterprise, a work against which, if feasible, the time required to complete it was urged as an insurmountable objection, the use of drilling machines, in connection with the powerful apparatus required for ventilation, seems unquestionably expedient.

As to the final result of the work now in progress for tunnelling the Alps under Mont Cenis, no man can predict with certainty what difficulties, now unseen, may not hereafter be encountered in an enterprise which, in extent and in character, has no parallel. Yet after seeing the ample means, far more ample than they now require, which the ingenuity of the engineers has placed at their disposal, in the application of compressed air for so many new, varied, and useful purposes, I am satisfied that they have found the best solution of the problem which the case admits, and that they hold an instrument fit to meet any thing which can now with certainty be foreseen. It is no longer a hope based upon an experiment, but it is a fact ascertained by months of uninterrupted experience,—witness the table I have taken from their records at Bardonnèche,—that they have already diminished by one half the time required for the work. At the rate of 80 metres a month, the rate now possible, the remaining 10,000 metres would be completed in less than 11 years. I have no doubt they will reach 100 metres, which would reduce it to 8 or 9. If they reach 120, which is the least at which they aim, it would bring the time required from now to its completion to a period not longer than that expended on some of the tunnels heretofore constructed. This is too much to expect. In this, as in all great works, there will be accidents, delays, and interruptions, which will considerably lengthen the time required. Several years must be added to any estimate based solely upon the results of actual and uninterrupted labor. But in view of the results already attained, I think it requires far more

boldness to pronounce the work impracticable than to anticipate its final success. For my own part, I believe that the ability which is now devoted to it is capable of bringing it to a successful completion, by means of the processes already in use and in part perfected, and within a time which hereafter will be called very short.

With the engineers at Turin I conversed at some length in relation to our own project, in which they seemed to take quite an interest. Mr. Grattoni objected most decidedly to the small section with which the tunnel has been commenced. This is a matter to which he has given much attention, in consequence of a discussion in relation to the size of tunnels for the railroads about to be built near the shores of the Mediterranean, and his experience and reflection have made him an earnest advocate for a large section wherever the length is considerable, even if there should be but a single track. A central shaft for our line he thought indispensable, and that it should be of large dimensions. As the two entrances are at the same level, and the line runs from east to west, so that the sun strikes on both sides, thereby equalizing to some extent the temperature, he thought the natural current of air through the tunnel would be less strong than if one valley were situated on the north and the other on the south of the intervening ridge. The shaft was all the more necessary for this reason; and with it he did not anticipate for us any difficulty in ventilation after the completion of the work. He did not think, from the specimens of the Hoosac rock which I showed him, that we should complete the shaft in less than 3 years, and if we were greatly troubled with water it might take longer.

Mr. Sommciller objected with equal decision to our small section. For purposes of ventilation alone, he thought the section originally designed for two tracks none too large for so long a tunnel, and he recommended that it should by all means be made of the proper size at the outset, and not constructed with a small section, to be enlarged at a future day. He was equally urgent that the central shaft should be constructed, and he felt that in the possibility of such a shaft we had an infinite advantage over their own work, where such an aid either for construction or ventilation is altogether beyond their reach. His drilling machines are not adapted to the work of sinking shafts, nor for use in the parts of the tunnel constructed by means of shafts; but he thought them perfectly able to work from the ends against such a rock as I exhibited to him, and said he felt confident of an advance of 50 metres a month at an end face, and should hope to

accomplish much more than this. From his experience in work by hand, he did not think we could make in that way a progress of more than 16 or 18 metres in our months of 25 days.

The machinery for compressing air, now in operation at Modane, he recommended as much better for our use than the compressors. If we have no water power, it would of course be practicable to compress the air by the use of steam, but the expense would be very great.

He acknowledged that the work at Mont Cenis was far beyond the bounds of a private enterprise or a commercial speculation, that it was too novel and uncertain in its character to be made a matter of contract, and thought the only way to deal with it was to carry it on at the expense and for the account of the two nations by day work, under the management of their own engineers, as is now done. The Hoosac project, though much inferior in magnitude and difficulty, had, perhaps, as it seemed to him, some analogy with that at Mont Cenis in this, as well as in some other features.

If machines are to be used, and his system put in operation, he thought we ought to have a water power equivalent to at least 200 horse power, available at each end of the tunnel; and he would prefer to have 500 at his disposal. Even this would be much less than the power at Bardonnèche and Modane. If steam is to be used, we should require at each end 2 steam engines of 150 horse power each, making four in all, either of which might work up to 200 horse power while the other is stopped.

If we should determine to use his system, he would be ready, upon receiving the necessary local information, to furnish an estimate of the cost of all that would be required, and would order for us from Cockerel any thing we might wish to have made at that establishment, with his latest improvements, or send us detailed working drawings of any of his machinery to be made here. He further suggested the expediency, in such a case, of our sending out some workmen, whom he would take pains to instruct fully in the use of all his apparatus.

HOOSAC TUNNEL.

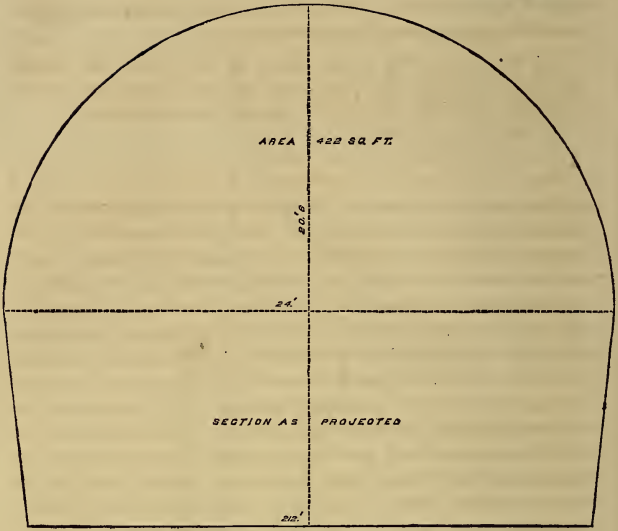
Having now given to the Commissioners an account of the various works visited in Europe, I presume it will be expected that I should state the conclusions to which I have arrived, as the result of what I have seen and heard abroad, and of my reflections thereupon.

As concisely expressed by the chairman of the Commissioners, in his

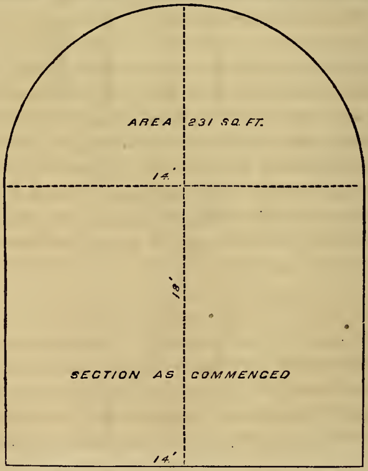
PLATE XXV.

PROFILE OF HOOSAC MOUNTAIN.

PLATE XXVI.



HOOSAC TUNNEL.—Section as originally proposed.



HOOSAC TUNNEL.—Section as commenced.

letter to me of July 21st, 1862, the three great questions upon which it was desirable to obtain information were, —

1st. What sort of a tunnel should be built under the Hoosac Mountain, to answer the purposes for which the work is intended?

2d. What would be the time required for its completion?

3d. What would be its probable cost?

First. As regards the *feasibility* of completing such a work, I entertain no doubt whatever. Having expressed the opinion that the tunnelling the Alps, an enterprise of vastly greater magnitude, is not beyond the limits of engineering skill, I cannot doubt that a tunnel can be made under the Hoosac Mountain, either by hand labor or machine labor, which may, after completion, be used without practical difficulty, and without the necessity of artificial means for its ventilation. For this purpose, however, I have as little hesitation in saying that in my opinion the small section with which the work has been commenced is entirely inadequate; that if it is to be built at all, its section throughout its whole length must be at least as large as that originally contemplated; and that with a summit in the centre, as now projected, 50 or 60 feet higher than either entrance, a shaft in the centre at least 12 feet in diameter, to be kept open for ventilation, is absolutely indispensable. If these two conditions of the full section sufficient for a double track, even if only one should be laid, and a shaft for ventilation at the summit, are not to be complied with, the whole work had better be abandoned. [Plates XXV., XXVI.]

Second. In estimating the time required for the completion of the tunnel after work shall have been actively resumed upon it, the question at once arises whether it shall be executed by hand labor or machine labor. What machinery the ingenuity of man may *hereafter* devise it is not necessary now to take into consideration. The subject has attracted the attention of inventors in more than one country; but inasmuch as the only machines ever put to the test of regular and uninterrupted work are those now in use at the tunnel under Mont Cenis, they are the only ones upon which it would be at all safe for us at present to base any calculations.

From the experience already gained at the Hoosac, and from similar work performed in other countries, I think that the utmost that that can be accomplished there by hand labor would be 60 feet in length per month of actual work, at one face. I believe that Mr. Sommeiller's machines, if properly put in operation, with ample power, and workmen skilled in their use, might be depended upon for

a progress of 120 feet at one face per month of 26 days, which is four days less than the working days of a month under the Alps. If the Hoosac Tunnel, like that at Mont Cenis, could have no shafts, and was to be executed entirely from the two end faces alone, the use of machines would reduce the time one half, and would unquestionably be expedient.

But the Hoosac has one shaft already completed, 3,000 feet from the western end, furnishing now four faces for work. Believing as I do that a central shaft is indispensable, I assume, of course, that it will be constructed. As soon as it is completed, the long portion of the tunnel between the eastern entrance and the western shaft, which is the portion which will determine the length of time required to complete the work, — because the westerly 3,000 feet can be finished long before the remainder, — will also have four faces for work. This, of course, affects the relative advantage of the use of machinery compared with hand labor, because the greater rapidity of advance can only be availed of at two out of the four faces, the machines not being adapted to work from the shafts. Moreover, the western portion of the tunnel, 3,000 feet in length, from the loose character of the soil and rock there encountered, would not at first, perhaps not at all, admit of the successful use of machines, — the greatest efficiency of which is against firm, hard rock. In all probability, that whole portion, differing much from the rest of the tunnel, would have to be completed by hand labor, partly from the western entrance, and partly from the western shaft. At a rate of progress of 60 feet per month at a face, this would take two years and one month, and during the same period work would also have progressed eastwardly at the same rate from the same shaft, a distance of 1,500 feet. The first application of the machines at the *westerly* end of the tunnel would therefore be more than two years from the time when the work would be resumed, and after a progress of 4,500 feet from the westerly entrance had been effected by hand labor.

The face of the rock at the eastern end of the tunnel, now opened for a distance of 2,300 feet, is in excellent condition for the immediate application of the machines. But to procure the machines from Europe, through the agency of Mr. Sommeiller or otherwise, to prepare power to run them, either by the erection of steam engines, or by building a dam across Deerfield River in order to create a sufficient water power, to lay the pipes, erect the necessary buildings, and to do all that is required to put the machines in operation, would probably require at the very least one year. It might consume considerably

more time than this. We may then assume that the first application of the machines at the *easterly* end of the tunnel would be one year or more after resuming operations, during which time the opening from the easterly end would have progressed at the rate of 60 feet per month, or 720 feet, and would therefore have reached a distance of 3,020 feet from the eastern entrance.

As regards the central shaft, 775 feet deep, I think it could be completed in three years, but I do not think it would be safe to count upon less time than this.

If the foregoing estimate of progress is correct, we should therefore find ourselves, at the end of three years from the time work is resumed, in the following situation: —

Progress from the Western end:		
25 months of hand labor, ...	4,500 feet.	
11 months of machine labor, 120 feet per month,	1,320	
	——	5,820 feet.
Progress from the Eastern end:		
At close of one year of hand labor, ...	3,020	
2 years' machine labor, 120 feet per month, . .	2,880	
	——	5,900
Completed, ...		11,720 feet.
Leaving to be completed out of the whole length of 24,100 feet, ...		12,380 feet.
		24,100

These 12,380 feet could now be completed from four faces, at the rate of 360 feet per month; that is, 240 feet from two end faces with machines, and 120 feet from two shaft faces with hand labor, and would therefore require 34½ months, or 2 years 10½ months. This, with the three years previously occupied, would make 5 years 10½ months. To this add the loss of time, unavoidable in making the change from one system of work to the other at the end faces, and the time required would be, at the very least, 6 years of actual work.

If hand labor alone should be used, we should have at the end of three years, when the central shaft is completed, —

Progress from the Western end:		
25 months of hand labor, ...	4,500 feet.	
11 months of hand labor at 60 feet per month, .	660	
	——	5,160 feet.

Progress from the Eastern end:

At close of one year of hand labor, ...	3,020 feet.	
2 years more of hand labor, at 60 feet per month,	1,440	
		4,460 feet.
Completed, ...	9,620 feet.	
Leaving to be completed, ...	14,480	
	24,100 feet.	

There would thus remain 14,480 feet to be completed from four faces, at the rate, therefore, of four times 60, or 240 feet per month. This would require 60 months, or 5 years, making in all 8 years from the time of resuming operations.

This would show a saving in time of only two years, possibly less, by the use of the Mont Cenis machinery instead of hand labor.

Is this a sufficient object to warrant its adoption in this case? I feel perfectly sure that the machines, as used thus far at Mont Cenis, have increased, rather than diminished the first cost of the work, even independently of the very large sums required to set them in operation. The saving which they effect is a saving in time, not in expense. At Mont Cenis the enormous and costly apparatus required for ventilation admits, and perhaps suggested, their use. At the Hoosac, such apparatus is unnecessary. At Mont Cenis, no shaft is possible to expedite construction. At the Hoosac, it is not only possible, but it is necessary for other purposes, and when completed it doubles our monthly progress, as the machines have doubled theirs. The power actually used even now at Bardonnèche, I judge from Mr. Carbillet's account, to be about 120 horses, and the engineers have both there and at Modane, a power at their disposal equivalent to 600 or 800 horses. For our case, we should probably have to construct a dam across Deerfield River, and erect steam engines at the western entrance, to furnish the necessary power to compress the air. Both would be expensive to erect and to maintain. Much, therefore, as I admire the ingenuity and skill which have been displayed in the introduction and successful use of these machines at Mont Cenis, I am led to the opinion that though not only expedient but almost necessary there, they are unnecessary and inexpedient for us. What the inventive genius of man may hereafter produce, we cannot tell, but in a sober, practical estimate, to be acted upon *now*, the experience of the past is a safer guide than the hopes of the future. With these machines in their present state, the great expenditure which they have thus far required for their

first establishment, the increased cost of the work they perform, and the limited gain in point of time which they would procure to us, dissuade me from recommending their adoption here.

My conclusion, therefore, is that as far as we can now foresee, the tunnel must be completed by hand labor.

I have given 8 years as the time of *actual labor* required. But in every such work there are contingencies and interruptions which make the whole time consumed much more than the time of actual labor, and I do not hesitate to say that the least time required for its completion will be 10 years, and that it may reach 12. Between these two limits it will probably fall.

Third. The probable cost of the work is a question of greater uncertainty than either of the two preceding.

The original estimate for the tunnel, with a section sufficient for a double track, 22 feet wide at bottom, 24 feet wide at the spring of the arch, and 20½ feet high, was $1,948,557, or $81 per foot in length. In this estimate very small provision seems to have been made for masonry for the sides and arches, much less than the experience derived from tunnels constructed in Europe would indicate to be generally necessary. It has there been found that even in hard rock the seams which are met with often render it unsafe to leave the ceiling unsupported for any great length of time. The rock at the eastern end of the tunnel, now entered for a length of 2,300 feet, is free from this objection, and appears remarkably favorable. Thus far it has stood well, and there are no signs of its being insufficient to remain firm without artificial protection. At the western end, however, it is quite the reverse, and it is already evident that much greater difficulty and expense will there be encountered, and that there will be a necessity for substantial arching.

The cost of excavating the portion already opened at the eastern end, which thus far has a section not much more than half as large as that which I have considered necessary, indeed, less than half, where the excavation must be made of sufficient size to receive a lining of masonry, is stated by the late engineer and contractors (House Doc. 325, p. 28, 1862) to have been about $50 per foot in length; and the work commenced at the western end is also there stated to have cost more than double this. The cost of European tunnels, as I have shown, varies exceedingly, and in some instances which I have mentioned has been enormous. Yet it should be noticed that this enormous cost is not for purposes of architectural display or embellishment, as might be the case in works of a different character, but is the inev-

itable and often unforeseen result of difficulties actually encountered there, as they may be encountered here, and which it was absolutely necessary to overcome, or abandon the enterprise. The cost of labor and machinery in Europe is at least as low as in this country, nor is there any lack of ingenuity and skill in applying them. We cannot, therefore, assume that in the construction of a tunnel we can adapt ourselves to our more limited means by contenting ourselves with a less costly article. The work must be completed, secure, and of sufficient dimensions. Nothing more is required there, and nothing less will answer here.

Taking into consideration the cost already incurred for the small section, the enlarged size which I have assumed to be necessary, the difficulty and expense already appearing at the western end, the manifest necessity of arches and side walls in that portion of the tunnel, and the great probability that they may be required to some extent in other portions, I should be unwilling to estimate the cost of the tunnel, complete, at any thing less than $125 per foot, or $3,000,000; and I think it more likely to exceed than to fall short of this estimate. Such work is extremely uncertain, and all estimates upon it are unsatisfactory. They are to be made with great diffidence, for experience has shown how many contingencies there are to swell the cost. But this I think may be safely said, that if the advantages to be derived from the tunnel are not an equivalent for an expenditure of $3,000,000 thereon, exclusive of interest, it is not worth while to pursue the undertaking.

Whether the very great advantages to the industry and commerce of the whole State anticipated from the opening of this new avenue to the great West, with diminished distance and diminished grades, and the great incidental benefits it would confer upon the active and enterprising population of the northern counties of Massachusetts,—advantages direct and incidental, which have often and forcibly been presented to public attention,—are sufficient to warrant the construction of a work of the character I have supposed necessary for the purpose, at such an expense of time and money, is a matter which it is not for me to discuss, but remains for the consideration of the Commissioners.

I am, gentlemen, very respectfully,

Your obedient servant,

CHAS. S. STORROW.

REPORT OF BENJ. H. LATROBE,

ON

THE HOOSAC TUNNEL.

REPORT ON THE HOOSAC TUNNEL.

BY BENJ. H. LATROBE.

BALTIMORE, October 1, 1862.

To Messrs. BROOKS, FELTON, *and* HOLMES, *Commissioners appointed under the Act of the Legislature of the Commonwealth of Massachusetts, approved April* 28, 1862, *in relation to the Troy & Greenfield Railroad, and Hoosac Tunnel.*

GENTLEMEN: At your request I have visited the Hoosac Tunnel upon the line of the Troy & Greenfield Railroad, and have made such an examination of the work as enables me to offer the following remarks in regard to it.

My visit was paid upon the 13th of August last, in company with James Laurie, Esq., civil engineer, appointed by you to examine and report upon the entire line of the road from Greenfield to North Adams. My observations were, by previous understanding, confined to the tunnel, to which I will therefore restrict my remarks, touching in turn upon the several questions which present themselves in connection with this particular work.

Upon my first view of this truly great undertaking, I said to myself, Here is, indeed, a tunnel through the *body* of a mountain. All tunnels heretofore executed have been through *spurs* or *crests* of mountains, the latter reached by long and winding developments; but the road, of which this tunnel is a part, advances undauntedly to the very foot of the lofty range which towers above it, and pierces it with one bold thrust from base to base. The Hoosac Tunnel is indeed the great and peculiar *feature* of the Troy & Greenfield road, and upon its practicability depends the motive to complete that road, which, without the direct through connection upon the line of low gradients which this tunnel would afford, would be a local line of little utility, except to the inhabitants of the Hoosac and Deerfield valleys. These fertile and populous valleys, indeed, require railway communication with their respective outlets upon the Hudson and Connecticut Rivers, and their

trade and travel may ultimately pay interest on the cost of such roads, one of which, in the Hoosac valley, is already in successful operation to the beautiful and opulent village of North Adams, whose thriving manufacturing establishments, together with the magnificent scenery of its vicinity, offer many attractions to the traveller.

My professional views upon the subject of the Tunnel I submit under the following heads: —

I. The Practicability of the Tunnel.
II. The Dimensions which should be given to it.
III. The best Manner of prosecuting the Work.
IV. The probable Time required to complete it.
V. The probable Cost of it when completed.

I. The *first* of these questions might be disposed of at once by the remark, that any work, of whatever magnitude, must be pronounced *practicable*, if the means for its accomplishment are within the reach of human power. The practicability of this work does not, however, present itself in this abstract form, for what has been already effected towards its execution, and that of other works of the same kind, is a sufficient earnest that its completion is but a question of time and money.

II. *The Dimensions which should be given to the Tunnel.* — Upon this point I have had no difficulty in reaching a conclusion, founded upon reasons which appear to me to override all minor differences of opinion. The single consideration that in a tunnel of such length derangements of the machinery of trains must, now and then, occur, and that with width enough for one track only, there would not be room enough on either side to operate in the necessary repairs, should, I think, of itself settle the question. The effect also upon a train of passengers, arrested for any length of time in a close vault, miles in length, through a lofty mountain, with insufficient space to permit them to escape from their place of confinement, should that become necessary, would have a fatal effect upon the character of the road as a passenger line.

The difficulties and dangers of conducting track repairs would also be imperfectly provided against by widening the work at intervals only. The considerations connected with ventilation are, however, of still more importance, and I feel well satisfied that a single track section would not here be admissible. Without following the learned Dr. Lardner in his computations of the weight and bulk of the gases

generated by the coal or coke required to carry a train through a tunnel of this length (see Breeze's Railway Glossary, p. 194), I will simply state, as the experience of the railroads within my knowledge, that in the longer tunnels, such as the "Kingwood," on the Baltimore & Ohio Railroad, inconvenience is at times felt from the smoke of trains, when following each other in quick succession, as in "convoys" of freight trains ascending the grade through the tunnel. This tunnel is 4,100 feet in length, and of double track section, with three ventilating shafts, about 1,200 feet apart. The engines burn bituminous coal, and, except in very calm, damp weather, the smoke and steam invariably occupy the upper part of the vault, leaving three or four feet above the rails almost free. The inconvenience would be greater, did not the train men manage their fires so as to have them as clear as possible on arriving at the tunnel. Nevertheless, it is necessary to stir the fuel, and even to throw in fresh, in passing through this tunnel less than a mile long. In one of six times the length, the fire would require to be frequently handled, as the time of passage at 15 miles per hour would be 18 minutes, and the consumption of coal 225 pounds, at but 50 pounds per mile. The Kingwood Tunnel affords a fair example upon this subject, as it is one of the longest as yet in the United States, upon a road passing much heavy freight, with engines burning coal, which must become the universal fuel of our locomotives. The coal used on the Baltimore & Ohio Railroad is chiefly from the Cumberland field, and remarkably free from smoke. Anthracite makes less smoke, but a more offensive and deleterious gas, and the same is true of coke.

The cases quoted to show an entire absence of inconvenience from smoke and gas in European tunnels, seem to have been those of passenger trains at high speed, and with small consumption of fuel during the transit, and with probable arrangements of other trains, so as to avoid this annoyance as much as possible. These tunnels, such as the Manchester & Sheffield, of 3 miles (which has 5 shafts), the Marseilles, of $2\frac{3}{4}$ miles, and the Blaisy, of $2\frac{1}{2}$ miles, were all of sections as large at least as the Kingwood. The smoke and gas affected, at times, the workmen engaged in arching the Kingwood and Boardtree Tunnels, on the Baltimore & Ohio Railroad, so as to make it expedient, in connection with other interruptions to the work, to resume the use of the temporary tracks over the top of the ridges through which the tunnels were driven, until the arching was completed.

For the reasons above stated, I am clearly of opinion that it would, to say the least, be extremely hazardous to the success of the Hoosac

Tunnel, to carry through the contracted dimensions given to the part of it already driven at its eastern end, and the inconveniences attendant upon which would be more and more seriously felt in the prosecution of the work itself as it advanced, and as its length grew more out of proportion to its breadth and height.

I would recommend, therefore, that this part of the section be enlarged to not less than 22 feet between the sides, with a height of 21 feet, if the roof be formed in a semicircle ; or the original form intended for the section may be re-adopted, having a width of 22 feet at bottom, and of 24 feet at a height of $8\frac{1}{2}$ feet, and crowned with a semicircular arch, making the whole height $20\frac{1}{2}$ feet; or, if the side walls be carried up higher, the crown may be flattened to 19 feet in height, with a roof of elliptic shape, if the material would bear it (which I thought probable), but, in every event, so as to preserve the same sectional area, of not less than 45 square yards. These dimensions suppose the rock to stand permanently without arching (of which there seems little doubt), and represent the interior lines of any vaulted support it might be necessary to give.

If the tunnel be thus made wide enough for two tracks, from the necessity of so doing for ventilation, space for repairs, and for the safety and comfort of passengers in case of detentions in the tunnel, it must be apparent that the other advantages of a double railway throughout the passage will greatly facilitate the movement of trains; and even if, in order to avoid the smoke of two trains at once, this advantage should not be fully availed of, yet the second track will be found of great use in the distribution of materials for repairs, and in passing around detained trains, which would otherwise wholly block up the tunnel. If, however, the meeting of trains in the tunnel be properly managed, there would be little or no inconvenience felt in having two in the tunnel at once, as, if they pass each other, as they should, on the summit level, the evolution of smoke from the train going down the grade would but slightly increase that already discharged by the ascending train. I attach much importance to the increased facilities for track repairs in the wider tunnel, as the condition of the rails in a tunnel, and especially one so long as the Hoosac, is of the first consequence, both as a guard against accidents and a help to traction, which the damp state of the rails always reduces in tunnels very considerably.

It may be said that if, to save present expenditure, the tunnel be graded for one track, it can afterwards be widened for two. This, I should consider next to impracticable in so long a tunnel as this.

Tunnels have indeed been widened, as upon the Philadelphia & Reading and the Lancaster & Harrisburg Railroads, but those tunnels were short (the longest 1,900 feet, with 3 shafts), and already wide enough for two tracks, although more width was desirable to accommodate increased width of cars and engines and secure safety to workmen. The transit of trains was maintained through the tunnels on the Reading road by great system, and the use of galvanic batteries for blasting. On the Lancaster road, however, the trains took the alternative route through Columbia while the enlargement of the tunnel was going on. Inasmuch, then, as the widening of the Hoosac Tunnel, after being brought into use, would be attended with almost insuperable difficulties, it should be made of the proper width in the outset.

III. *The best Manner of prosecuting the Work.* — In a work of such magnitude, it is manifest that every measure, not inconsistent with the objects it is intended to accomplish, should be resorted to for hastening its completion and reducing its cost. My examination of the ground at both ends of the tunnel and across the intermediate mountain, led me to the following conclusions as to the mode in which the work should be carried on when resumed: —

1. Assuming that no change for the better can be made in the adjustment of the tunnel, which seems to have been established with great care, I would suggest a modification of the *grade*, as shown on the profile. Thus, the ground at the west end is obviously so unfavorable for tunnelling, that the road bed should be raised thereat as much as practicable, without breaking up the system of gradients upon which, with a view to the utmost economy of working the road, it has been located from Troy to Greenfield. We were informed by Mr. Field, a professional gentleman connected with the work before its suspension, and who gave us his company and much useful information during our examinations, that the maximum rise eastward through the Hoosac valley, from Troy to North Adams, was $39\frac{6}{10}$ feet per mile. The level at North Adams station cannot be materially changed without injury to the connection at that important point; and if the ruling grade just mentioned be adhered to, an additional height, not exceeding 25 feet, can be attained at the west end of the tunnel, by increasing to the maximum the existing grade from North Adams to that point. It may, indeed, be questioned whether an increase beyond that maximum, say to as much as $52\frac{8}{10}$ feet per mile, would not be advisable for the mile and a half between North Adams and the tunnel, in order to raise the road bed still higher at the latter

place. This would require the use of assistant power to take to the tunnel the trains arriving at North Adams from the west, and this might perhaps be furnished, without material expense, by the engine which would be kept to arrange trains at that important station. I will, however, assume the grade at the west portal of the tunnel to be raised but 25 feet, which will afford great relief, by lifting the road bed out of material of the worst character for tunnelling, as the experience gained in driving 550 feet through it has shown. This portion of the tunnel, which has broken in from the surface in part, should, in any event, be converted into an open cutting, and the new portal be placed at its eastern end. It is much to be regretted that the western portal could not be placed still farther east; but that would require an inadmissible depth of approach cutting, and the troubles of tunnelling through the disturbed strata, mixed with clay and boulders, which extend for about half a mile up to where the steep slope of the mountain begins, which must be encountered. At the shaft, which has been sunk about 3,550 feet from the west portal as first fixed, the stratification seems to have assumed a more regular formation and dip, which may extend farther west than the superficial form of the ground would indicate. This will be ascertained when drifting westward from the shaft is resumed, and the point up to which the rock will sustain itself without arching is determined. Masonry, to support a good part of the roof from the west portal towards the shaft will probably be required, but as in this case the excavation will be proportionably easier, I have not, in the estimates of cost hereafter submitted, made any special allowance for lining the excavation.

I would not advise that the projected grade of $26\frac{4}{10}$ feet per mile *within* the tunnel, west of the summit, be increased. The gain of 25 feet more elevation will be sufficient, and the bottom part of the shaft thus cut off will be valuable as a sump, or well, for receiving the water during the intervals of pumping. I would, however, change the grade of $26\frac{4}{10}$ feet to one of $39\frac{6}{10}$ feet per mile, *east* of the summit, in the tunnel. The heavier grade being in favor of the heavier trade, would be free from objection, and by employing it we should bring the new and old grades together at the eastern portal of the tunnel, as shown in the profile which I herewith append as a part of this report. The change through the already excavated part of the tunnel would raise the grade but about 6 feet at the west end of the excavation, and this, coupled with the proposed increase in height and width, would occasion but little loss in the work done heretofore. The new grades through the tunnel would then stand thus, very nearly: —

	Feet.
Ascending eastward from west portal at $26\frac{4}{10}$ feet per mile,	10,868
Level on the summit, ...	2,000
Descending eastward to east portal at $39\frac{6}{10}$ feet per mile, .	10,682
Total length of tunnel reduced 550 feet at west end, . . .	23,550

The original length being 24,100 feet, as reported.

By this elevation of the summit level 25 feet, the shafts, of which I will presently speak, will be that much shortened, the length of level will remain unchanged, as also the grade west of it, while that east of it will be increased as stated. The road height at the level might, indeed, be kept as before, and the level extended each way to meet the grades on each side of it; but any lengthening of the summit's level would seriously impair its drainage; and if the grades were flattened so as to meet it at its original terminations, they would not carry off the water so freely. For these reasons I prefer the new arrangement which I have proposed.

2. I suggest that two shafts be sunk in the valley between the mountain summits, about $\frac{3}{4}$ of a mile apart in horizontal distance, measured on the grade of the road. The eastern shaft, numbered 3, would be 750 feet deep from the surface of the ground to the floor of the tunnel, and the more westerly one, numbered 2, would be 1,050 feet in depth. A small decrease in the depth of the latter might be had by inclining it slightly eastward from the perpendicular, but the advantage gained would not probably be sufficient to induce a departure from the usual vertical position. These shafts I consider essential for the threefold purpose of expediting the work, insuring its correct alignment, and for better ventilation. The single shaft originally proposed would promote these objects, but much less fully, and the two can be completed as soon as the one, with allowance for the greater depth of the western one. I will not say more of the shafts under this head, as their advantages as well as their dimensions and cost will be noticed again.

IV. *The probable Time required to complete the Tunnel.*—There is much room for difference of opinion and for speculative discussion under this head. I propose, therefore, to present in brief an estimate, founded, as far as practicable, upon the experience of works already executed, and apply it to the suggested mode of conducting the one under consideration. Our safest guide in this inquiry is naturally the work done at this very tunnel. Numerous are the examples of other tunnels, long and short, wet and dry, hard rock and soft rock, needing

arching or timbering as they went on, or not needing it; but comparisons between works dissimilar in most of their features would mislead us. We will first, then, see what has been actually effected at the Hoosac, and afterwards, by considering what has been accomplished at other works most nearly resembling it, we may judge to what extent the results already obtained may be realized in an improved degree by improved modes of operation.

It seems, then, that in the 13 months, from September 1, 1858, to October 1, 1859, the eastern section of the Hoosac Tunnel advanced in the hands of the contractors at the average rate of 39 feet, linear, per month; that in the next 6 months, to April 1, 1860, the progress was 35 feet per month, and that from thence during the suceeeding 9 months, to July 1, 1861, it averaged 56 feet per month. We see here a progress somewhat irregular, yet, on the whole, showing a considerable improvement in speed; the falling off during the 6 intermediate months being due, perhaps, to some disturbance in the contractors' arrangements, which appear to have been of occasional occurrence during the progress of the work. The increase in rapidity of advance between the first and third periods is very marked, and promised well for the subsequent progress, had the work been continued. As the distance from the portal extended, however, the difficulties of transportation and ventilation would of necessity increase, and the question would arise whether they would be balanced by the improved skill and experience which would be brought to its management. We remark here, that the suggested enlargement of the section of the tunnel should not make its progress slower, as the larger space and increased force would fully compensate for the increased material to be moved, and the widening of the present narrow section can be effected without additional delay.

The nature of the rock and the quantity of water to be encountered in the more central parts of the tunnel, are the two most doubtful elements of progress and expense. The excavation of 2,300 feet at the east, and the shaft of 300 feet near the west end, disclose very similar material, — a mica and talcose slate, with disseminated quartz, in veins and lumps of irregular size and form. The surface outcrop over the line of the work appeared to show the same sort of rock, as far as we could judge at the time. Mr. Laurie, I learn, is making more minute examinations between the two mountain summits, where the rock was too well covered to be seen. The dip of the strata is very high, steeper on the esatern than the western slope, and in opposite directions, the ledges leaning towards each other. The mountain I should

judge to be but one range, although with two distinct summits, and an intermediate basin or trough scooped out by the denuding action of water. This basin is now drained by two brooks, which unite near the line of the tunnel. We could not ascertain whether the stratification conformed in any degree with the concavity in the crest of the mountain. My impression was that it did not, but that the eastward dip on the eastern slope towards the Deerfield River changes upon an anticlinal axis, somewhere in the intermediate hollow, to the westward dip, which is manifest on the westward slope towards the Hoosac River. I notice that the eminent geologist, President Hitchcock, regards the Hoosac range as not having been "lifted up by granite or any of the igneous rocks pushing upwards from underneath, but crowded together from the sides or edges, so as to cause a folding together of the strata." Higher authority could not be adduced upon such a subject, and we must assume it to be correct until disproved by the future development of facts. The opposite direction of the dip on the two slopes is not conclusive evidence of upheaval; and even were it so, the granite, or other igneous rock, may not have thrust itself as high up as the proposed level of the tunnel. President Hitchcock's observations upon a section of the same range farther north, would show that mica slate composes the entire body of the mountain, without intrusive veins or dikes of trap or other rock of that class.

I am disposed, therefore, in estimating time and cost, to treat the rock still to be perforated by the tunnel and shafts as resembling that already excavated. Should it turn out to be, in part, more difficult, that will be an incident to works of this character and extent which it would be wise to consider of possible occurrence, but the apprehension of which should not deter us from entering upon an enterprise destined to accomplish such important results.

So much for the probable character of the rock. As to the flow of water to be met with, it is, as President Hitchcock observes, very difficult indeed to risk a prediction. The nearly vertical position of the strata would seem to favor the percolation of water downward from the trough between the summits; but water finds its way, perhaps, as often through cleavage, seams, and fissures in rocks as along their beds. The amount of water in the shaft already sunk was, I believe, not excessive while the work was going on, although we found it full of the accumulations of a year and more. The stream issuing from the eastern drift of the tunnel was of less volume than I should have expected, and would require a large increase to seriously embarrass the working. But without speculating farther upon these points, I

will offer an estimate of the time it should probably take to complete the tunnel, explained by the appended profile, showing the manner in which I would propose to conduct its workings, with a view to the utmost expedition.

It will be seen from the profile, that the two additional shafts over the central part of the tunnel, which I propose under a previous head, would, according to the estimated progress of the different workings, bring them together about the same time. The depths of the shafts, as marked, may not be exact, as my only means of measurement are derived from the profile annexed to the published report of Mr. D. L. Harris to the Committee of the Massachusetts legislature, which, I presume, cannot be far wrong. The profile which I have constructed from that of Mr. Harris, and which I append as a part of my present report, fully explains the mode of operation I propose.

I estimate that from the open ends of the tunnel the average progress per month will be 50 feet, or 600 feet per annum, while the shaft workings will make but two thirds of this, or 33⅓ feet per month, or 400 feet per annum. This, I find, was the proportion between the two kinds of working in the Kingwood Tunnel, upon the Baltimore & Ohio Railroad, during a period of 31 months, the time occupied in excavating that tunnel. Mr. Harris, I notice, allows better rates for both portals and shaft workings, and I think he may be right. If so, the more rapid advance in the tunnel will compensate for any failure to attain the speed I have assumed for the sinking of the shafts, for which I have allowed four years as an average for the two, or 209 feet per annum, or ⅔ of a foot per day, or ⅓ more than allowed by Mr. Harris.

I think my estimate for the shafts is a safe one. The shaft already sunk near the west end of the tunnel made a speed of about 7⅓ inches per day; and although the central shafts will be from 2½ to 3 times as deep, yet with the experience to be acquired, and the perfect machinery to be employed for drainage, ventilation, and elevation of material, there can be no reasonable doubt that the work can be done even more rapidly. The shafts of the Kingwood Tunnel were sunk at the average rate of 25 feet per month, or nearly 1 foot per day, through sandstone and slate, and the last month's work at the bottom averaged 47 feet per month, through compact argillaceous rock, or nearly 2 feet per day at a depth of 160 feet,—the machinery employed by the contractors being very imperfect. The shafts of the Stump-house Mountain Tunnel, on the Blue Ridge railroad of South Carolina, made as much as 15 feet per month through an excessively

hard granitic rock, full of quartz veins and saturated with water. The body of the Kingwood Tunnel was driven 92 feet per month from the portals, and 62 feet per month from the shafts, through very compact slate rock, with occasional silicious beds.

If it be, then, admitted that the shafts can be made to reach the grade in four years, as estimated, and that a progress of 50 feet per month from the ends, and $33\frac{1}{3}$ feet from the shafts, can be effected, the tunnel can be completed in $9\frac{1}{2}$ years from its resumption.

In these estimates I assume the common mode of working by hand drills. The novel and ingenious machinery for driving the tunnel, either by an annular groove cut around the circumference or a cylindrical bore in the centre of the section, I could entertain no confidence in, from their first suggestion as they require the machines to do too much and the powder too little of the work, thus contradicting the fundamental principles upon which all labor-saving machinery is framed. My examination of the machine intended to make the central bore of 8 feet diameter, which still remains at the western end of the tunnel, only confirmed my conviction that such machinery had the elements of failure in its structure and mode of operation, to say nothing of its economy. The larger machine, designed to cut the annular groove of 24 feet diameter, which had been in operation at the east end, had been removed, so that I could not examine its manner of working; but I could not doubt, from the specimen of its performance at that place, that it could be "made to go," — for a certain time. I could only look upon it, as upon the other, as a misapplication of mechanical genius.

On a proper system of drilling the ordinary blast hole by suitable machinery, I should place much more reliance; and as this mode of applying mechanical power to that purpose, through the medium of compressed air, appears to have been established successfully in the great tunnel at Mont Cenis, I have no question it will be used at the Hoosac Tunnel, with such improvements as American ingenuity is apt to make upon European invention. Should this be the case, the work in the body of the tunnel will be greatly expedited, and the time required to open it be materially shortened. The present rate of progress at Mont Cenis was reported in the London Mechanics' Magazine, of September, 1861, to be 1 metre ($3\frac{1}{4}$ feet) per day at each heading, in a very similar rock to that of the Hoosac. Fifty per cent. increase on this rate was expected to be made by farther improvements in the machinery, but I am not informed whether this has been realized. If but three feet per day, or say 80 feet per month,

can be made in the Hoosac, then the drifts from the eastern portal can be advanced so as at the end or $3\frac{3}{4}$ years, within which it is estimated the eastern shaft will be down to grade, there will be but 3,895 feet east of that shaft to drive; and this, at 80 feet per month from the portal and 60 feet for the shaft working, would be completed in a little over two years (28 months), and the whole time, allowing for slower working from the deep shaft, would be reduced to 7 instead of $9\frac{1}{2}$ years.

This result I look upon as very probable, as it assumes only the same rate of speed as that actually attained a year ago at Mont Cenis, and which was reasonably expected to be further improved.

In regard to the use of compressed air to operate machinery at a distance from the compressing powers, I would refer to an article in the Journal of the Franklin Institute for June, 1857, page 367, containing a description of such an application in the Govan coal mines, Glasgow, Scotland, where an air engine was worked at a distance of half a mile from the steam engine used to condense the air, and with a loss in the transmission of but one pound in twenty in elastic power. The success of the Mont Cenis machinery, however, renders further reference to the subject unnecessary; and I would, in concluding this head, only call attention to the happy circumstance connected with the use of condensed air, — that its discharge, after performing its work at the heading of the tunnel, supplies the fresh air required thereat for respiration and expulsion of the smoke of the blasts, thus securing a very fortunate combination of two important objects at the expense attendant upon one.

V. *The probable Cost of the Tunnel when completed.* — A few statements under this head will suffice, for if (as is too common in such cases) estimates of cost were to be arrived at by striking an average between the cost of numerous other tunnels constructed under wholly different circumstances, much space might be filled with speculations upon irrelevant examples. It will be better to see what the part of the tunnel already excavated has cost, and apply that to its future progress, with suitable allowances. Mr. Harris states that the 2,300 feet of tunnel at the east end, 14 feet wide and 18 feet high, with a section of $8\frac{1}{2}$ square yards, cost about $\$37\frac{1}{2}$ per linear foot, or \$4.41 per cubic yard. The cost of the 550 feet driven, as he says, "through a secondary? (certainly a *much disturbed*) formation, differing entirely from the material of the mountain proper," he estimates to have cost "\$100 per linear foot for excavation and propping up," to which he adds \$40 per foot for arching. But as this part of the

tunnel will become an open cutting, should my suggestion for raising the grade there be adopted, and as the material between it and the western shaft (No. 1) may be different and much less difficult, I will not treat it separately from the remainder of the work.

Having no means of accurately ascertaining the cost of the work done so far, I will estimate only for what remains to be done to complete the tunnel, assuming that to occupy 9½ years from the date of its resumption.

ESTIMATE.

1. Widening 2,300 linear feet of tunnel at east end from a section of 8½ to one of 15 cubic yards per linear foot, 14,950 cubic yards, at $3 per yard, . .	$44,850
2. Sinking two circular shafts of 750 and 1,050 feet depth and 20 feet in diameter, 20,997 cubic yards, at $20 per yard, ...	419,940
3. Excavating 21,250 linear feet of tunnel, containing 15 cubic yards per foot, near 318,750 cubic yards, at $5 per yard, ...	1,593,750
	$2,058,540
Add for contingencies and superintendence, 5 per cent.,	102,927
	$2,161,467
Add interest at 6 per cent. on this amount for ½ the time allowed for the work (4¾ years), ...	616,018
Two million seven hundred and seventy-seven thousand and four hundred and eighty-five dollars, ...	$2,777,485

If the time can be reduced from 9½ to 7 years, which I look upon as quite probable, the interest account would be lessened $162,110, and the total cost to $2,615,375, or in round numbers, to something over two and a half millions of dollars. It may be said that the prices assumed are somewhat arbitrary. True, they are; and although they seem to me to be safe, they may prove insufficient should the interior of the mountain turn out different from what President Hitchcock supposes. I am content, however, for the present, to rest upon his authority; and should the rock prove no harder than it has shown itself thus far, the probabilties of a cheaper working with the machine drills are as great as those of a dearer one from a worse rock. If, at the outset of the work, in a narrow tunnel of 8½ yards section, the cost did not

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exceed \$$4\frac{41}{100}$ per cubic yards, an addition of upwards of 10 per cent. to that price should, in a tunnel of nearly twice that section, compensate for increase in transportation, drainage, and ventilation.

The price assumed for the shafts seems to me sufficient for so capacious an area, which I have supposed of a diameter large enough to embrace nearly the whole width of the tunnel, and of a circular form, as most easily preserved in sinking them, at the same time allowing length enough for accurate adjustment of the line of drift. These shafts will not only be valuable for ventilation and alignment but for exploration of the strata as they descend, so as to prepare in some degree the tunnel workings for what they may encounter. Without the shafts, the work, at the reported speed at Mont Cenis, say 80 feet per month, would require nearly 13 years for its completion. I regard them, therefore, as an essential feature of the work; but I would at the same time remark, that if, when the tunnel is resumed, it should, by experience at Mont Cenis or elsewhere, be shown that the progress in the tunnel can be quickened so as to make a single shaft insure its completion in the 6 years I have estimated as the shortest time it may take, then the second shaft might be dispensed with, although I think the work would suffer in other ways, more than to the amount of any pecuniary saving that might thus be effected.

CONCLUDING REMARKS.

I have, as will be seen, drawn some of my material from the report of Mr. Harris, which, as it was made in official form to a legislative committee, and by a party not apparently prepossessed in favor of the tunnel project, I have regarded as reliable authority on the points upon which I have referred to it. I had no other means at hand, indeed, of obtaining the leading documentary facts — such of the papers in the contractors' office at North Adams as were accessible during our visit not exhibiting much of the detail of the work.

I do not feel called upon to discuss the policy of prosecuting this great work, which, after the full investigations which have been had before the legislative and other bodies, who have considered its merits, may, I presume, be regarded as thoroughly established. The only questions remaining are those of time and cost, which, of course, have their bearing upon the question of prosecution or abandonment. It is manifest that if, even in the somewhat distant future, may be discerned a prospect of public benefit which would call for the completion of the work, there should be as little time as possible lost in resuming it.

If the enterprise really possesses the merits claimed for it (which I cannot doubt), half a million, or even a million, more or less, should not stay its progress; for, by the time that could be spent, the increased magnitude of all the public interests depending upon it will be fully prepared to meet the outlay.

As to rivalries with other lines, the experience of our country, young as it is, has already shown their results to be less injurious than previously apprehended, and to be indeed in a great measure imaginary; the stimulating effect of new lines upon local improvements, and the consequent increase of population and production, being lost sight of by the proprietors of present routes, which they fear will be prostrated by the threatened competition for a share in their through business.

I beg, gentlemen, to submit the preceding remarks, with a proper sense of the imperfect manner in which I have been able to treat the subject; and,

With great respect, I am,

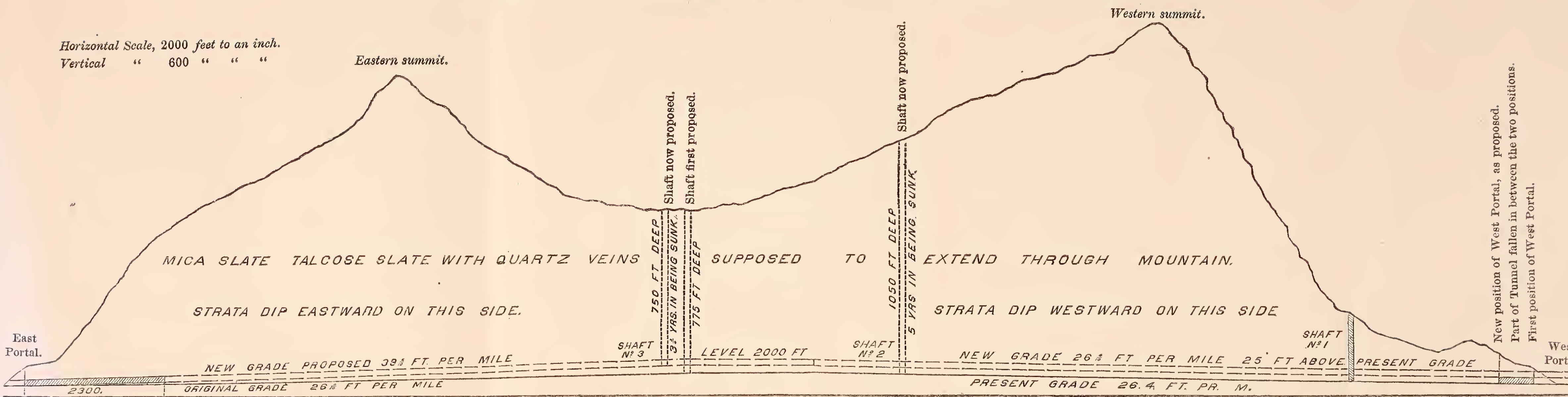
Your obedient servant,

BENJ. H. LATROBE,

Civil Engineer, &c.

PROFILE OF THE HOOSAC MOUNTAIN TUNNEL,

Showing mode of Working the Tunnel, suggested in the Report of B. H. Latrobe, Civil Engineer, October 8 1862.



2300 →	2700 →	3000 →	2215 ←	2215 →	← 1600	1800 →	← 3100	← 1260	← 960	360 →	← 1440	550
Part already driven for single track.	$4\frac{1}{2}$ years' working in Tunnel while Shafts are being sunk.	5 years' working in Tunnel to its completion on junction with Shaft working.	$5\frac{3}{4}$ years' work from Shaft after it is sunk to grade.	$5\frac{3}{4}$ years' work from Shaft No. 3.	$4\frac{1}{2}$ years' work from Shaft No. 2.	$4\frac{1}{2}$ years' work from Shaft No. 2.	5 years' work in Tunnel to its completion on junction with Shaft working.	$2\frac{1}{10}$ years' work after opening from west end.	$2\frac{4}{10}$ yr's' work from Shaft No. 1.	$2\frac{4}{10}$ yrs' work fr'm Shaft No. 1.	$2\frac{4}{10}$ years' work from West Portal.	Part of W. end of Tunnel turned into open cutting.

WORKING SECTIONS OF TUNNEL AS ABOVE.

From East Portal, already driven, ...	2,300 feet.	
" " " first $4\frac{1}{2}$ years' work, ...	2,700 "	
" " " second 5 years' work, ...	3,000 "	Total, 8,000 feet.
" Shaft No. 3, $3\frac{3}{4}$ years in being sunk, . . .	—	
" " No. 3, $5\frac{3}{4}$ " eastward, ...	2,215 "	
" " No. 3, $5\frac{3}{4}$ " westward, ...	2,215 "	" 4,430 feet.
" " No. 2, 5 " being sunk, ...		
" " No. 2, $4\frac{1}{2}$ " eastward, ...	1,600 "	
" " No. 2, $4\frac{1}{2}$ " westward, ...	1,800 "	" 3,400 feet.
" " No. 1, completed.		
" " No. 1, $2\frac{4}{10}$ years eastward, ...	960 "	
" " No. 1, $2\frac{4}{10}$ " westward, ...	960 "	" 1,920 feet.
" West Portal, $2\frac{4}{10}$ " eastward, ...	1,440 "	
" " " $2\frac{1}{10}$ " "	1,260 "	
" " " 5 " "	3,100 "	" 5,800 feet.

Grand Total, 23,550 feet, as shortened 550 feet at West Portal, the original length being 24,100 feet.

The broken lines show the changes suggested in the plan of the work, the arrows showing the direction of the working. These are made to balance exactly, only to indicate the general plan of operations, and its intended and probable results, which, if realized, would complete the Tunnel in $9\frac{1}{2}$ years.

B. H. L.

REPORT OF JAMES LAURIE,

ON

THE TROY & GREENFIELD RAILROAD AND HOOSAC TUNNEL.

REPORT ON THE TROY & GREENFIELD RAILROAD.

BY JAMES LAURIE, C. E.

HARTFORD, CONN., January 10, 1863.

To J. W. BROOKS, ESQ., *Chairman of the Board of Commissioners on the Troy & Greenfield Railroad, and Hoosac Tunnel.*

SIR: I herewith respectfully submit a Report on the Surveys and Examinations made in connection with the Troy & Greenfield Railroad, and Hoosac Tunnel, together with the following maps and plans:—

1. A General Map of the Country from the Connecticut River to the line of the State of New York.

2. Two Maps, showing the present location of the road from Greenfield to North Adams, on a scale of 400 feet to an inch, with various alterations proposed.

3. A Profile of the Road, showing the grades and present condition of the work, with the amount remaining to be done.

4. A Map and Profile of the line, surveyed by Deerfield Centre.

5. A Book containing Cross-Sections, taken at distances 100 feet apart.

6. A Plan of Green River Bridge.

7. A Plan, exhibiting various sections of Tunnels. And,

8. A Box, containing a Section of the Hoosac Mountain, showing the dip and course of the strata, with specimens of the rock found at the surface.

Very respectfully, I am, sir,

Your obedient servant,

JAMES LAURIE.

REPORT.

THE project of tunnelling the Hoosac Mountain is no new or recent scheme. As far back as 1825, a Board of Commissioners, with Loami Baldwin as engineer, were appointed to ascertain the practicability of making a canal from Boston to the Hudson River, in the vicinity of the junction of the Erie canal with that river.

They examined the country by way of Worcester, Springfield, and the Westfield River; and also by Fitchburg, the Miller and Deerfield Rivers, making the village of North Adams a point common to both routes. In their report, after describing the rugged character of the country up the middle and north branches of the Westfield River, the increased distance, and the difficulty of obtaining a sufficient quantity of water, on the summit levels, to meet the consumption of a canal, they state, "there was no hesitation in deciding in favor of the Deerfield and Hoosac River route." (Commissioners' Report, 1826, p.141.)

At the Hoosac their examinations were extended both to the north and south of the present line of tunnel, with a view to discover some other route by which it might be avoided; but increased distance and lockage, and difficulty of procuring water, induced them to give preference to the tunnel. In their report they say, —

"There is no hesitation, therefore, in deciding in favor of a tunnel; but even if its expense should exceed the other mode of passing the mountain, a tunnel is preferable, for the reasons which have been assigned. And this formidable barrier once overcome, the remainder of the route, from the Connecticut to the Hudson, presents no unusual difficulties in the construction of a canal, but, in fact, the reverse being remarkably feasible."

It was, perhaps, fortunate for Massachusetts that she did not embark in this work, as railways, which were shortly afterwards introduced, are much better adapted to overcome the obstacles presented by the physical character and topographical features of the country traversed.

The Stockton & Darlington Railway was opened for the conveyance of freight and passengers in 1825, and the Quincy Railroad, for the conveyance of stone, in 1827. The success of these works turned attention to a railroad communication with the West; and, in the year 1828, surveys were made by James F. Baldwin, Esq., under the direction of a Board of Commissioners, of three several routes, viz., by Greenfield, by Northampton, and by Springfield. The preference was given to the latter. The Commissioners, in their report, remark that:

"It being thus ascertained that the southern route affords the greatest facilities for the construction of the road, it was deemed important to inquire whether it would afford equal accommodation with either of the others to the trade of the intermediate country between Boston and Albany. On this point, also, the result was in favor of the southern route. The population of the towns through which it passes, according to the last census, is 73,632, and if we add that of the towns west of Middlesex county, within ten miles of the route, 137,175. The population of the towns which the northern route passes through, is 57,526, and if we add that of the towns within ten miles of the route, the number is 115,892."

The work was not immediately commenced, but Massachusetts never lost sight of having a direct and improved means of communication with the Hudson River and the West, until it was finally effected by the completion of the Western Railroad through to Albany in the year 1842.

Meanwhile charters had been granted for other roads through a more northern portion of the State; the Fitchburg was in process of construction, the Vermont and Massachusetts followed, and their extension westward was occasionally brought before the public, until, in 1848, application having been made to the legislature, a charter was granted authorizing the construction of a railroad from the terminus of the Vermont & Massachusetts Railroad, at or near Greenfield, through the valleys of the Deerfield and Hoosac to the State line, there to unite with a railroad leading to the city of Troy. The capital stock authorized was $3,500,000, and the road was required to be located within two years, and constructed within seven years.

The location was filed in the clerk's office of Franklin county, November 26, 1850, and in Berkshire county, November 29, 1850. But no progress was made in the construction of the road, the efforts to obtain subscriptions to the stock not proving successful to any great amount.

In 1851, and also in 1853, the company applied for a State loan, but were refused. In 1854, however, they were successful. An act being passed (Chap. 226, Acts of 1854), authorizing a loan of the State credit "to enable the Troy & Greenfield Railroad Company to construct the Hoosac Tunnel." By this act the State loaned its credit to the amount of $2,000,000; conditioned that $600,000 should be subscribed to the stock, and 20 per cent. actually paid in; that 7 miles of road should be built, and 1,000 feet of tunnel be completed, to entitle the Company to $100,000 of scrip; and, for every additional

issue of scrip, required that a further payment should be made on the stock, another 1,000 feet of tunnel be completed, and certain specified lengths of road built; so that in the end the whole road and tunnel would be completed before the last issue of $200,000 of scrip was made by the State.

As security for the repayment of the loan the Company were to build the road from their own resources, and give a mortgage to the State on the entire road and tunnel, and on the franchise and other property of the Company. The estimate upon which the amount of the loan was based, was made by the first engineer, A. F. Edwards, Esq., and was for a double track tunnel.

The estimated cost of the tunnel was . . .	$1,948,557 00
And of the road and equipment	1,401,443 00
Total	$3,350,000 00

Notwithstanding this liberality on the part of the State, the Railroad Company found themselves unable to procure the means required for the construction of the road, or to obtain the requisite amount of valid subscriptions to entitle them to the benefit of the loan. In the following year (1855) the legislature authorized the several towns through which the railroad passed to subscribe to the amount of three per cent. of their last valuation to the capital stock of the Company; but this failed to be responded to at the time, and in 1857, when an act was passed modifying the Loan Act, which, however, was vetoed by Governor Gardner, only 520 shares had been subscribed for by towns, or about one fifth of the amount authorized by law, and on this subscription the town of Adams only had paid to the amount of $1,400. (Governor Gardner's Veto Message, May 26, 1857.) The uncertainty of the cost of the tunnel, and the long time required for its completion before any return could be expected, deterred capitalists and business men from embarking in the work.

In 1855 a contract was made with E. W. Serrell & Co., under which some work was done, and another in January, 1856, for the construction of the road and tunnel for the sum of $3,500,000, they subscribing to the stock to the amount of $440,000. In the latter contract it was provided that the corporation should, on or before the 15th day of May, 1856, raise $100,000 of available stock over and above what had then already been subscribed, and that the whole amount, including the old stock, should not be less than $210,000, in available cash subscriptions.

About this time the Railroad Company applied to the legislature for a State subscription of $150,000 to the stock, the legislature to have the privilege of appointing part of the Board of Directors; but this failed to be granted, and the Company, being unable to procure the amount of subscriptions stipulated in their contract with Serrell & Co., it became inoperative.

A new contract was made with H. Haupt & Co., July 30, 1856, by which the Railroad Company agreed to pay the sum of $3,880,000 for completing the road and tunnel. Payments to be made in manner following: —

$2,000,000	in the bonds of the State of Massachusetts.
900,000	in the 6 per cent. mortgage bonds of the Company.
598,000	in capital stock.
382,000	in cash, payable in such proportions monthly, as required for use on the estimates of the engineer.
$3,880,000	

H. Haupt & Co. agreed to assume the stock subscriptions of E. W. Serrell, and Serrell & Co., amounting to 5,987 shares, conditioned that no cash assessment should be laid on the same, but that the assessments on the said stock should be paid by the performance of the contract "in stock credits."

The corporation, however, proving unable to comply with the stipulations as to cash payments, another contract was made between the same parties, February 18, 1858, in which, after reciting that, "whereas every attempt thus far, to procure new, or collect old subscriptions to the capital stock of the Troy & Greenfield Railroad Company, since the execution of the former contract with H. Haupt & Co., have proved unsuccessful, it is agreed that the contractors shall release the Railroad Company from the cash payments required by the former contract, and themselves assume the labor of collecting and procuring subscriptions, and of carrying on and completing the Troy & Greenfield Railroad, and the Hoosac Tunnel." It is also stipulated that, "H. Haupt & Co. shall so construct the road as not to exceed the gradients in each direction which exist, or may hereafter exist, permanently, on other portions of the line between Troy and Boston; and if, in construction of the road, any sharper curves should be used than are found in ordinary use on other parts of the line, they shall be changed at the expense of the contractors, at or before the time of completion of the tunnel; and if any trestle

work or temporary bridging should be used in the construction of the road, this also shall be changed by and at the cost of the contractors, and replaced by permanent structures, as soon as practicable after the completion and opening of the whole line." All former contracts between the same parties are annulled and cancelled.

Under this contract, the contractors were to receive

$2,000,000	in the bonds of the State of Massachusetts, to be exclusively appropriated to work done upon the tunnel.
900,000	in mortgage bonds of the Company.
1,100,000	in cash, to as great an extent as cash subscriptions can be procured, and the remainder in the capital stock of the Company.
$4,000,000	

H. Haupt & Co. were also to be paid such sums in addition as may be required for right of way, if this item was paid for by them. But no expenditure was required on their part for depot buildings or rolling stock, as in the previous contract.

Under the previous contracts, the tunnel had been commenced and a portion of the road graded west of North Adams. Both were now vigorously prosecuted, and through the exertions mainly of Mr. Haupt, the several towns through which the railroad passes subscribed to the stock to the full limit authorized by law. These subscriptions, however, were mostly conditional that certain portions of the work should be completed before the town scrip in payment of the stock subscribed should be issued, and were, therefore, only to a limited extent immediately available.

By means of these subscriptions, assessments on individual stock, and advances made by the contractors, the work was prosecuted during the season. And the officers of the Company, by certifying that 20 per cent had been paid in on 6,000 shares of stock, — using for this purpose a portion of the shares of H. Haupt & Co., on which, by the contract there were to be no cash assessments laid, — were enabled, October 6, 1858, to draw the first instalment of $100,000 of State loan.

In 1859 (Chap. 117, Acts of 1859), an act was passed making various modifications in the Loan Act of 1854, dividing the payments on account of the tunnel between "heading" and "completed tunnel;" also authorizing it to be constructed "of size not less than 14 feet in width and 18 feet in height from the bottom to the top of the excavation."

In the following year, the contractors having failed to procure a sufficient amount of subscriptions to the stock to enable them to prosecute the work on the road to completion, application was made to the legislature for a diversion of a portion of the tunnel loan to this purpose; and the legislature (Chap. 202, Acts of 1860) authorized $650,000 to be taken out of the $2,000,000 to be applied to the road east of the tunnel, the payments to be made monthly, on the certificate of the State engineer.

This Act provides that "such monthly estimates shall be based upon a width of road bed at grade of 15 feet on embankments, 17½ feet in side cuts, and 20 feet in thorough cuts;" and that "the deliveries of scrip shall be at the rate of $50 for each lineal foot of tunnel, divided between heading and full-sized tunnel, in the proportion of $30 for each lineal foot of heading, and $20 per lineal foot for the remaining excavation." Also, that "the scrip shall be delivered on the road, in the proportion which the value of the work done and the materials delivered each month, bears to the estimated cost of the whole work and materials required on the portion of road aforesaid."

"No expenditures shall be required merely for the purposes of ornament, but the work shall be substantially performed, and the rails shall weigh not less than 56 pounds to the lineal yard: for any defective materials or work, a proportionate amount of scrip shall be withheld."

As the State was now virtually to pay for the whole work, although nominally only loaning their credit, it was deemed necessary by the legislature to investigate whether the requirements of the several Acts had been complied with when previous payments were made. And, by Kimball's Report of 1860, and the documents and evidence attached thereto, it appears that payments had been obtained from the State before the "work required to be done" had been completed "in amount and quality, according to the requirements of the Acts" (p. 33). This appears to have been accomplished through the agents of the State, by their making ambiguous certificates and returns to the Governor and Council, suppressing the truth as to the length of road and tunnel actually and in fact completed according to the requirements of the Act. When, therefore, in July, 1861, it was discovered that the greater amount of scrip appropriated to the construction of the road had been already issued, — and there still remained a large amount of work to be performed to complete the same in a substantial manner, the then State engineer refused to give

a certificate for the amount claimed by the contractors, and the work was abandoned.

I consider it unnecessary in this place to enter into any discussion of the questions raised between the contractors and State engineer, further than to remark that, involving, as did the several laws in aid of this project, the payment of large sums by the State, and involving, as did the Act of 1860, a supervisory and discretionary power on the part of the State engineer to determine the character of the road and work, the State was unfortunate in its own appointments; but as the action of its agents was to favor the contractors, the State and not the contractors, has suffered.

Had Haupt & Co. entered into their contract subsequent to the appointment of a State engineer, and his approval of the location, curvatures, and character of work, the case would have been different; but their contracts had been made years previously, and the works were in progress under them, and every change and modification made of the line and character of the work was to reduce the cost, and for the benefit of the contractors.

Mr. Haupt, in his letter of January 31, 1862, addressed to the "Chairman and Gentlemen of the Joint Committee," uses the following language: "It is not, and I believe never has been, denied that the work was constructed in exact conformity to the plans, specifications, slopes, and dimensions approved and prescribed by the first State engineer and his successor, and was carried out in exact compliance with their wishes and instructions. Upon the State engineer, therefore, upon the agent and officer of the State, upon the representative and protector of its interests, and not upon the contractors or the Company, must the responsibility rest, if the work really exhibits any want of substantiality."

He also, on the part of the contractors, states that the suspension of the work was due to their reposing "too great confidence in the good faith and financial ability of individuals and towns, and of the State authorities of Massachusetts." * In making these latter statements he evidently forgets that their contract was not with the State, but with the Troy & Greenfield Railroad Company, and that himself and partners controlled, and were, in fact, the corporation, owning more than one half of the whole stock subscribed.

Looking at the legislation on the subject from the beginning, the State has done every thing to forward the completion of the road short

* Haupt's Letter of July 31, 1862, page 13.

of performing the work themselves. The railroad company and the contractors have been unfortunate in promising too much and performing too little, and perhaps unfortunate in relying more upon political management than on the merits of the work for its accomplishment.

NORTH ADAMS TO STATE LINE.

The construction of this portion of the road ($6\frac{5}{8}$ miles) was commenced by Gilmore & Carpenter, in 1851, under a contract with the Troy & Greenfield Railroad Company, and a large portion of the grading done during that and the following year, when they suspended. Under the contract with Serrell & Co. some progress was also made, and the work was finally completed by Haupt & Co. in 1858. This portion is now leased to the Troy & Boston Railroad Company for the sum of $8,000 per annum, the lessees keeping the road in repair.

SOUTHERN VERMONT RAILROAD.

This road, which forms the connecting link between the Troy & Greenfield and Troy & Boston Railroads, is about 6 miles in length, through the town of Pownal, Vermont, and was built by H. Haupt & Co. in 1857–8, under a contract with the Southern Vermont Railroad Company, for the sum of $200,000; payable, $150,000 in the first mortgage bonds, and $50,000 in the capital stock of the corporation. In 1860 the control of the road was secured to the State of Massachusetts by the issue of $200,000 of 5 per cent. bonds, and it is now operated by the Troy & Boston Railroad Company, under a lease from the Southern Vermont Railroad Company, at an annual rent of $12,000 a year, the lessees keeping the road in repair and making all improvements.

EXPENDITURES.

Under the several laws in aid of the Troy & Greenfield Railroad, the State has issued scrip and paid interest to the following amounts :

1858,	Oct. 6.	Sterling bonds,	5 per cent.		£22,500
1859,	Oct. 4.	"	"	"	11,200
1860,	Jan. 3.	"	"	"	11,300
"	Mar. 1.	"	"	"	6,800
				Carried forward,	£51,800

	Amount brought forward,	£51,800	
1860, Oct. 8.	Sterling bonds, 5 per cent.,	18,000	
" Dec. 12.	" " "	26,500	
1861, Jan. 5.	" " "	7,500	
" Feb. 18.	" " "	5,800	
" Mar. 7.	" " "	4,900	
		£114,500	$508,888 88
" May 8.	Federal bonds, ...	$85,500	
" June 27.	" "	37,500	
" July 10.	" "	38,000	
" " 11.	" "	55,000	
" " 12.	" "	500	
			$216,500 00
1861, Sept. 4.	Int. on Sterling bonds, due Oct. 1, 1861,	$13,705 84	
" Oct.	Interest on Federal scrip, due Oct. 1, 1861,	4,363 00	
" Nov.	Interest on Federal scrip, due Oct. 1, 1861,	25 00	
1862, March 4.	Interest on Sterling bonds, due April 1, 1862,	15,446 67	
" April.	Interest on Federal bonds, due April 1, 1862,	6,437 50	
" Sept. 5.	Interest on Sterling bonds, due Oct. 1, 1862,	16,262 22	
" Oct. 1.	Interest on Federal scrip, due Oct. 1, 1862,	5,275 00	
" Nov. 12.	Interest on Federal scrip, due Oct. 1, 1862,	137 50	
			$61,652 73
1860, May 4.	Purchase of Southern Vermont R. R. Federal bonds,	. . . .	200,000 00
	The State has also appropriated for settlement of land damages, and other claims against the Troy & Greenfield Railroad Co., ...	. . . .	175,000 00
	Making the total advances by State,	. . . . .	$1,162,041 61
	In addition to the above, the town subscriptions actually paid amount to		$126,500 00
	Carried forward,		$1,288,541 61

Amount brought forward, ...	$1,288,541 61
And the cash payments on stock, subscribed by individuals, amount to	114,954 00
Making the total cash expenditure, exclusive of contractors' advances, if any, amount to, ...	$1,403,495 61

This brief sketch of the history of the Troy & Greenfield Railroad brings us down to the last session of the legislature, at which you were appointed a Board of Commissioners, with full power to investigate the whole subject, and advise what is best for the interests of the State ; and, having been appointed by you to make a survey of the road and an estimate of the cost of completing the same, I will now proceed to give the results of my examinations.

DESCRIPTION OF THE LINE.

The Troy & Greenfield Railroad, as at present located and partially built, leaves the Vermont & Massachusetts Railroad at a point about $\frac{3}{8}$ of a mile south from the Greenfield depot, and, by a sharp curve to the west, crosses Green River by a bridge at a height of 80 feet above the water. This bridge is the most important structure on the road, and will again be referred to. Having once gained the western bank, which is an elevated plain or table land, the line curves gradually to the south and pursues the general course of the Deerfield valley, crossing three or four ravines 30 to 70 feet in depth, which are either bridged or trestled over. No other serious obstacle is met with until we reach the vicinity of Stillwater, a distance of 5 miles from Greenfield. Here several rock cuttings are encountered, and for $2\frac{1}{2}$ miles beyond, the line is mainly along steep and rocky hill sides, and the curvatures are sharp and numerous, until we reach Bardwell's Ferry. At this place, the bank of the river is quite steep, and composed of a clayey earth, which slides badly.

Stickney's and Shingle Brooks, which form deep ravines, were proposed to be bridged or trestled over, most of the material being delivered on the ground.

Three quarters of a mile beyond Bardwell's the road crosses the Deerfield River obliquely, the curves at each end of the bridge being of 716 feet radius. Hence to Shelburne Falls the line keeps the southern bank of the river, — clay, rock, and gravel cuttings alternating. Some of the side cuttings in clay are quite formidable, and numerous slips have taken place.

Through the village of Shelburne Falls there is a curve of 716 feet radius. About one mile west of the village a rock excavation of 1,000 feet in length and 16 feet greatest depth is encountered, cutting off a sharp bend of the river ; thence, the line is over favorable ground, mostly interval and meadow lands, except for about 2 miles opposite East Charlemont, where steep clay hills are met with, to the second crossing of the Deerfield River, near the junction of Cold River. Thence, the line either occupies the present travelled road, or runs parallel with it to Zoar Bridge. Near this, the river makes a deep bend to the right around a projecting spur of high land. The original location cut through this spur by a tunnel 1,200 feet in length. The present line keeps on the north side of the river, and passes around the bend by curves of 955 feet radius, increasing the distance about two thirds of a mile. Thence to the base of the Hoosac Mountain, at the great bend of the Deerfield, where the tunnel begins, the ground is favorable.

The mountain rises abruptly, attaining an elevation of 1,415 feet above the level of the tunnel, in a distance of 6,200 feet, then it falls off for a distance of 4,000 feet, to the valley of Cold River, which is 790 feet above the grade line, and, rising on the other side, attains an elevation of 1,695 feet above grade in a distance of 8,700 feet. The descent from this last summit, which is elevated 2,507 feet above tide, to the shaft now sunk on the western side of the mountain, is 1,415 feet in a distance of 3,666 feet. From the shaft to the present western end of the tunnel is 3,008 feet. The profile of the mountain, it will be observed, presents two summits, between which lies the valley of Cold River.

The whole length of the proposed tunnel, between the present portals, is 25,574 feet, or 4.844 miles. From its western end to the railroad station at North Adams, is 2.03 miles.

Wherever the line impinges on the main hills in the Deerfield valley, rock or clayey earth is met with, but there are occasional diluvial plains, composed of sand and gravel, and where they occur, the road is of easy formation.

DISTANCES.

From Greenfield to Stillwater, rails laid, ...	5.36	miles.
" Stillwater to Shelburne Falls, partly graded, .	7.77	"
" Shelburne Falls to east end of tunnel, do. do.,	17.02	"
Length of tunnel, ...	4.84	"
" west end of tunnel to North Adams, . . .	2.03	"
	37.02	miles.

The maximum grade going west is 58.6 feet per mile, for a length of 6,700 feet, and coming east, 40 feet per mile, for a length of 11,100 feet. The least radius of curvature is 716 feet, of which radius there are 6 curves, embracing a length of 4,192 feet. $8\frac{28}{100}$ miles in length of the road is on curves of less than 1,000 feet radius. The whole amount of curvature is 4,030 degrees, or more than eleven complete circles, averaging over the whole road 109 degrees to a mile. The whole length of straight line is 21.89 miles, and of curved line, 15.13 miles.

Tables (Nos. 1 and 2) at the end of this Report give details of grades and curvature, of which the following are brief abstracts : —

GRADES. — From Greenfield to North Adams.

INCLINATION.	Ascending west. Miles.	Descending west. Miles.	Total Miles.
Level, ...	. . .	. . .	2.518
From 0 to 10 feet per mile, ...	1.875	. . .	1.875
10 to 20 " "	5.781	2.386	8.167
20 to 30 " "	3.578	4.255	7.833
30 to 40 " "	2.796	3.316	6.112
40 to 50 " "	4.394	. . .	4.394
50 to 58.63 " "	6.119	. . .	6.119
	24.543	9.957	37.018

CURVES.

No. of Curves.	Description.	Length of each Class of Curve.	Total Curvature.
8	2° or 2865 feet radius,	0.946 miles.	4030°
17	3° or 1910 " "	1.480 "	
35	4° or 1432½ " "	3.483 "	
11	5° or 1146 " "	0.942 "	
72	6° or 955 " "	7.101 "	
3	7° or 818.5 " "	0.387 "	
6	8° or 716.2 " "	0.794 "	
152		15.133 "	
	Straight line, ...	21.885 "	
		37.018 "	

The valley of the Deerfield is by no means favorable for obtaining long straight lines. It is generally narrow, and bounded on either side by high and steep hills, broken occasionally by watercourses. These hills, however, except at some particular points, do not rise so abruptly as to prevent curvature of moderate radius being obtained by resorting to heavy cutting and embankment. On the original location made by Mr. Edwards, this was done; and the alignment, as put on file in the offices of the county clerks presents no very objectionable features, comparing favorably with that of the Western Railroad, where passing through the same range of mountains. His location had been made to obtain the best possible line which the ground admits of, and in some respects exhibits much boldness of design. The original contracts were made on Mr. Edwards's location. It has, however, in the main been abandoned, and a new one adopted, evidently with the intention of obtaining the cheapest possible road, without reference to its character. There are many cases where even a moderate expenditure for grading would have rendered curves unnecessary, or very much increased their radius.

Some changes, also, have been made in the line and grades of the tunnel. By the original location, the eastern entrance was in a ravine, formed by the action of a mountain torrent. After attempting to

change the course of this stream, and excavating the road bed up to the rock, at an expense of about $5,000, some slides took place, and the line was moved about 150 feet to the south, where the tunnel now enters the solid rock, and runs parallel with the ravine. This change increased the length of the tunnel about 500 feet.

At the western end the line also was moved, and the grade lowered some 30 feet, with the expectation of sooner reaching solid rock. This was unfortunate, as the rock appearing on the surface proved to be a mere detached mass, soon cut through. The tunnel at this end has been increased nearly 1,000 feet in length.

The terms of the Loan Act, providing for payments on account of the tunnel, while nothing was allowed for open cutting, had probably some influence in determining these changes, and especially that at the western end.

The following tabular statement exhibits a comparison of the two locations from Greenfield to North Adams:—

STATEMENT.	Present Location.	Original Location.	Difference.
Length of road, ...	37.02 miles.	35.88 miles.	1.14 miles.
Maximum grade west, ...	58.63 feet.	46.02 feet.	12.61 feet.
" " east, ...	40. feet.	41.93 feet.	1.93 feet.
Total rise and fall, ...	1046.16 feet.	866. feet.	180.16 feet.
Least radius of curvature, ...	716.2 feet.	955. feet.	238.8 feet.
Total curvature, ...	4030 deg.	2287 deg.	1743 deg.
Length of straight line, ...	21.89 miles.	18.57 miles.	3.22 miles.
Length of curved line, ...	15.13 miles.	17.31 miles.	2.18 miles.
Length of curves 955 ft. radius or under, .	8.28 miles.	0.19 miles.	8.09 miles.

For details of grade and curvature on original location, see Tables, Nos. 3 and 4.

SLOPES.

Almost all the slopes of earth cuttings, so far as completed, have been taken out, one horizontal to one vertical, or to an angle of 45 degrees. This is less than the slope which all earth cuttings on railroads will eventually assume, when exposed to the action of the weather. If sufficient inclination is not given to them in the first instance, slides will constantly take place, filling up the side ditches and obstructing the road.

In New England, New York, and the Western States, as a general rule, the slopes are made $1\frac{1}{2}$ horizontal to one vertical, or a quantity of material is taken out of the cuttings equal to what this slope would require to be removed. Frequently clay cuttings are taken out wide at the level of the road bed, with nearly vertical sides, and left to slope themselves. It is found that slips and washes from them very soon fill up the ditches; and as it is not always convenient to clean them out immediately, it is in some cases considered better to give greater width of road bed and use a steeper slope, thus giving space for the material washed down to accumulate until it can be removed by means of cars. Few or none of the slopes of earth cuttings on the Troy & Greenfield Railroad now stand 1 to 1. They have generally run down to nearly $1\frac{1}{4}$ to 1, and many slides have taken place, particularly on the portion of road from Bardwell's Ferry to Shelburne Falls. These slides cover the road bed several feet in depth.

Steeper slopes than $1\frac{1}{2}$ to 1 have been attempted on several roads. On a portion of the New York & New Haven Railroad, built by R. Schuyler & Co., under a lump contract, the slopes were at first taken out to 1 to 1, which effected some saving in first cost, but the Railroad Company had to continue at work on them until they were reduced to about $1\frac{1}{2}$ to 1, or were supported by expensive bank walls — the origin and occasion for which in a great measure was due to the slopes not having been originally made flat enough, nor sufficient land taken to allow of slopes of $1\frac{1}{2}$ to 1. The Pennsylvania Central Railroad was also constructed with slopes of 1 to 1 in earth; and in the annual reports of the road we find repeated notices of extraordinary expenses being incurred in the removal of numerous washes and slides, until 1859, when it is stated that "the sloping has added much to the safety of the road and reduced the expense of watching." Two years later, however, we again find them reporting that "numerous slides of rock and earth have added largely to the expense of maintenance of way."

There are several reasons why the slopes on the Troy & Greenfield Railroad should even be made flatter than usual. The general course of the rock stratification in the Deerfield valley is nearly at right angles to the course of the road, and the seams and fissures give vent to springs, which cause slips to take place. Many of the earth cuttings are full of boulders and detached pieces of rock, which are liable to roll down and obstruct the road, and from the great number of sharp curves, rendering it impossible for the engineer to discover obstructions on the track until close upon them. It is of great importance that the cuttings should be so sloped that boulders and other material will

not roll down. A single accident to a train might result in damages amounting to more than the entire cost of reducing the slopes to $1\frac{1}{2}$ to 1.

It is true that some portions of the banks of the Deerfield River are composed of a peculiarly stiff and tenacious earth, which, when free from water, now stand, in a few instances, at a somewhat less slope than $1\frac{1}{2}$ to 1. This occurs where their bases have been washed away by the action of the river, and they are protected from the action of the weather by a matting of roots and brush.

On the railways of England the slopes of earth cuttings are rarely ever made less than 2 to 1. This in a great measure prevents their slipping, admits of their being covered with soil, and sown with grass seed, which insures, after a few years, slopes not liable to be washed.

TRESTLE WORK.

About 1,800 feet of trestle work is now completed on the line of the road, and material is delivered for about 500 feet more. This trestle work is built mainly over ravines and water courses 20 to 70 feet in height, to save masonry and embankment. A few of the smaller structures are well put together and of sufficient strength, but the larger ones are generally of a very unsubstantial character. They are bedded mainly on the natural soil. Wooden pins are used for fastenings, and much of the bracing is of sapling timber of only 4 to 6 inches diameter. I would consider it necessary, before passing locomotives over these structures, to strengthen them materially, especially the bracing; also to use iron for the more important fastenings.

CULVERTS.

The foundations of the culverts are rarely sunk low enough, and the openings have not been made of sufficient size. This is evidenced by the fact that already 14, nearly $\frac{1}{3}$ of the whole number of box culverts built, have either been blown up from not being able to pass the water, or are undermined so that portions of the walls have tumbled down. No arch culverts are used, although the size of several of the streams is such as to have rendered their adoption advisable.

RIVER WALLING.

Some of the bank walling also has fallen down from its own weight and the pressure of the embankment. In some other instances the workmanship and material are so indifferent that the walls cannot be relied upon to resist the jar and action of heavy locomotives and trains of cars.

GREEN RIVER BRIDGE.

This bridge is 706½ feet in length. There are seven spans of 65 feet, and two of 126 feet, supported on stone piers, except at the western end, where temporary trestles are used. With the exception of the long spans, the bridge is on an irregular curve of 764 to 818 feet radius.

The superstructure, which will be presently referred to, I consider unsafe and insufficient. I propose, therefore, to fill in solid with embankment about 260 feet of the curved portion adjoining the Vermont & Massachusetts Railroad, where the depth is from 25 to 64 feet. This will leave two spans of 126 feet and three of 65 feet.

Of the present masonry, three piers only will be available. Their foundations are 74, 68, and 62 feet below grade; they are 18½ by 7 feet at top, and have a batter of one foot in 24 on the sides, and are built of rubble masonry laid in mortar, except some 10 or 15 feet of the upper portion of the west pier, which is laid dry, and was intended to be grouted. Both stone and workmanship are very inferior — not better than is frequently used for culvert masonry. I know of no bridge of the height of this where the masonry is so poor, and I have some doubts of its sufficiency to resist the jar and strain it will be subjected to by the passage of heavy trains. The piers should have been built of large stone, well bonded together, and with dressed beds and joints. If, on further examination, it should be deemed advisable to take them down, the loss will not be much; they contain about 1,000 cubic yards of masonry, the cost of which could not have exceeded $5 per yard. If they were entirely removed a new location could be made, making the whole of the bridge portion on a straight line. No wooden structure can be made creditable on the present location and piers, and I think it deserving of serious consideration whether it would not be advisable to construct stone arches over the public road and Green River, and make a solid embankment across the valley. The quantity of embankment required, in addition to that estimated, is 130,000 cubic yards.

Superstructure. — The long spans are 122 feet between the points of support, and are divided into three equal spaces or panels. Vertical posts are placed at the points of division, underneath the chords which support the road way. The foot of these posts rest on wrought iron cylinders, which are supported by the main suspension and tie rods, forming what is known as a suspension trussed girder. The depth of the truss is 19½ feet from centre to centre. Counter

ties are inserted in each panel, and at the points of their intersection cylinders are introduced, from which radiating braces support the chords at intervals of about 11 feet.

The chords are placed 14 feet apart from centre to centre, and are each composed of 4 pieces of timber 5 by 12 inches, separated two inches by parting blocks placed 10.1½ feet apart. The gross sectional area of each chord is 240 inches. No lower chords are used, the suspension and tie rods supplying their place.

The suspension rods, at their upper ends, are attached to floor beams notched on to the chord timbers, and at their intersection with the counter ties, and at their lower ends pass into the cylinders, the nuts being secured on the inside. These cylinders were originally of cast iron, but the failure of one of the spans having been imputed to them, they were being replaced with wrought iron when the work was suspended.

The main suspension rods were originally 5 in number, of $1\frac{1}{16}$ inch iron to each chord, but two additional have been added, giving a sectional area of 15.65 inches of iron.

The lateral bracing is confined to the chords upon which the floor timbers rest, and consists of diagonal braces, 5 by 4 inches, and iron ties of 1 inch round iron. The diagonal vertical bracing over the piers consists of 2 rods of $1\frac{1}{4}$ inch round iron.

On subjecting to calculation the strength of these spans, with an assumed load of 4,000 pounds per foot, including the weight of the bridge, the following results are obtained.* The main suspension rods of each truss are subjected to a strain of $8\frac{1}{4}$ tons, of 2,000 pounds, per inch. The chord timbers are subjected to a strain of 790 pounds per inch. The lateral ties, — assuming the force of the wind at the usual standard of 40 pounds per square foot, and the surface exposed to its action, when a train of cars is upon the bridge, at 15 superficial feet for each foot in length, — are strained 19 tons per inch, and the end braces 1,820 pounds per inch. The diagonal vertical bracing over the piers is subject to a strain of from 18 to 20 tons per inch.

* In 1856 I was employed by the Board of Railroad Commissioners of the State of New York to examine a number of the wooden and iron railroad bridges in that State; the following estimate of the load per running foot, which bridges have to sustain in ordinary practice, was adopted for spans of 150 feet. The Commissioners were authorized by law to test all railroad bridges by the passage of a train of 5 cars weighing 150 tons, moving at the rate of 40 miles an

Wrought iron, of good quality, is found to be capable of sustaining 10 tons per inch without destroying its elasticity, but it is not considered safe to approach this limit in railroad structures. In practice, 6 to 8 tons, of 2,000 pounds, depending on the faith or the temerity of the builder, form the usual limits. In the Green River Bridge we find it subjected, with the assumed load, to a strain of from 8¼ tons on the main rods to 20 tons on the bracing.

In Howe, Pratt, and other bridges, the timbers are generally of such dimensions that the length unsupported does not exceed 12 to 15 diameters (or side of the square) of their least dimensions, and when of these proportions, are not subjected to a greater working strain than 800 pounds per square inch. In the Green River Bridge the separate sticks, and also the chords, are without fastening for a length of 20 diameters, and should not be subjected to a greater strain than 600 pounds per square inch. If they were 40 diameters they could not be relied upon for more than 240 pounds; whereas, we find the strain on them to be 790 pounds on the chords, and 1,800 pounds on the bracing, per square inch.

While no bridge can be considered secure, unless in addition to the other strains coming upon it, it can resist the action of the wind at a

hour. This is fully equivalent to 2,500 pounds per foot, and the bridges were required to be of sufficient strength to sustain and support double the weight or stress which would be produced by this load in motion.

	Load per running Foot.	
	Wooden Bridge, covered.	Iron Bridge.
Weight of bridge, including rails, cross ties, flooring, &c.	1500 lbs.	1250 lbs.
" " saturated snow, ...	660 "	540 "
Load: Two first-class locomotives, with snow plough and loaded cars, ...	1600 "	1600 "
" due to action of wind at 30 lbs. per square foot,	980 "	590 "
" " " " of brakes, &c.	260 "	270 "
	5000 "	4250 "

pressure of 40 pounds per square foot, which is that of a hurricane, we must bear in mind that they are of rare occurrence in New England, and I have no doubt there may be other bridges weak in this respect but even at 20 pounds per square foot, which is that of a storm or tempest, the bracing of the Green River Bridge is inadequate.

The details of bearing surface for washers, butting joints, &c., appear originally to have been made in defiance of all practical rules of the strength and resistance of materials, but as they were in process of alteration when the work suspended, I deem it unnecessary to particularize them.

The plan of the bridge has evidently been designed with reference to employing the least possible quantity of material, and is generally such that the failure of one of several parts involves the destruction of the whole — the structure forming the mere skeleton of a bridge. There is nothing in the plan, however, to prevent a bridge of sufficient strength being built on it by properly proportioning the parts. But, this not having been done in the first instance, it would now cost as much to perfect it as to take it down and adopt some other plan, using such of the material in the present structure as may be found suitable.

Mr. Haupt, in support of his assertion that the bridge is of sufficient strength, brings forward the great viaduct over the Susquehanna, on the Pennsylvania Railroad, as an instance where a Howe Bridge has less sectional area in the chords than the Green River Bridge, although the spans are greater; and states that "the lateral bracing is precisely the same, both in plan and dimensions." He forgets, however, to mention that nearly 1,000 feet of the Susquehanna viaduct was destroyed by an ordinary gale of wind before it was entirely completed, for want of proper and sufficient bracing. He also forgets to state that the main support of the Susquehanna viaduct is in the arched ribs attached to the trusses, which have a much larger sectional area than the chords. By his own calculations, and in his own language, "the arches alone are sufficiently strong to bear, with perfect safety, 3 or 4 times the greatest load that can ever come upon the bridge." (Haupt on Bridge Construction, p. 175.)

Even, however, if there were other bridges of not greater strength than the Green River, this would not justify its adoption. The numerous failures which take place show that many are constructed of insufficient strength.

ESTIMATE OF COST.

Were the road intended for local accommodation only, the present location might answer, as the amount of business, present or prospective, in the Deerfield valley, would scarcely warrant the construction of a first-class road; indeed, beyond Shelburne Falls, it is questionable if any kind of railroad would pay working expenses. But as a great through line is contemplated, — a line to compete with existing roads constructed on the best principles, for the transportation of freight at low rates, — I would deem it of great importance to improve the alignment as far as may be practicable.

The great amount of curvature of small radius is, perhaps, the most objectionable feature, and one which, originally, could have been avoided by a comparatively small addition to the cost. But any improvement that can now be made will be partial, unless the whole line is revised and a higher standard adopted. So much of the grading has been performed, however, on the present location, it is questionable whether, — in view of the uncertainties connected with the prosecution and completion of the tunnel, and the many years that must elapse before the road can be used as a through line, — it would not be advisable, in the event that the road, or any portion of it, is to be undertaken at present, to complete it temporarily on the present location, and use it until the tunnel is completed and the success of the work established.

It could then be improved to such extent as deemed advisable. From the amount of work already done on the grading it will not, perhaps, make much difference in the eventual cost; the saving of interest on present outlay would meet the increased expenditure at a future day. I have, therefore, and in accordance with your request, made the following estimate on the present location, excepting at two or three points, where, from the small amount of grading required, the line can be improved without involving much loss of expenditure heretofore made.

With respect to the bridging and trestle work the case is different. The present structures are temporary and insufficient, and I have provided for entirely new bridges, and for filling in the trestle work, with one exception. This is the trestle work across "Hawkes' Ravine," about 3 miles from Greenfield. It is nearly 70 feet in depth, with a stream and public road at the bottom. To make an arched covered way for the public travel would be very costly, and, believing that an

alteration of the road may be effected, I have, for the present, estimated for a wooden superstructure on stone piers.

The foregoing remarks apply to the present location being substantially adopted. Should the route which has been surveyed, and will presently be described, — which leaves the Vermont & Massachusetts Railroad east of the Deerfield River, and runs by Deerfield Centre and Stillwater to Bardwell's Ferry, — be adopted, it involves the entire abandonment of $7\frac{7}{10}$ miles of the present road.

I have allowed for reducing the earth slopes to $1\frac{1}{2}$ to 1; the material, where not otherwise wanted, to be used in filling the present trestle-work.

In this estimate, I have included only such station buildings, fixtures, and equipments as are necessary to operate the road for local accommodation; and in a subsequent estimate of the cost of the road and tunnel, have provided for the additional expenditure that will be required for these items to operate the road as a through line.

ESTIMATE OF COST OF COMPLETING THE ROAD FROM GREENFIELD TO THE TUNNEL.

From Greenfield to Bardwell's Ferry.—Length, 7.71 *miles.*

10,000	cub. yds. in grading depot at Greenfield.		
46,000	" " filling at Green River Bridge.		
116,777	" " filling trestle work.		
36,209	" " completing road bed and embankments.		
208,986	cub. yds. earth (of which 37,029 is furnished by reducing slopes), ...	at $0 20	$41,797 20
1,850	cub. yds. solid rock, ...	" 1 20	2,220 00
500	" " loose rock, ...	" 0 50	250 00
915	" " box culverts and drains,	" 3 00	2,745 00
2,704	" " arch culverts, ...	" 4 50	12,168 00
1,350	" " bank wall, ...	" 2 00	2,700 00
500	" " rip-rap, ...	" 0 80	400 00
2,810	" " river-bridge masonry, .	" 8 00	22,480 00
1,638	" " road-bridge masonry, .	" 4 00	6,552 00
	Foundations of masonry, ...		1,700 00
		Carried forward,	$93,012 20

			Brought forward,	$93,012 20
440 feet superstructure of Green Riv. Bridge	at $22	$9,680 00		
170 feet superstructure at Hawkes' Ravine,	" 15	2,550 00		
30 feet superstructure of road bridges,	" 8	240 00		
		$12,470 00		
Less value of materials in present bridge,		2,470 00		
				10,000 00
15,000 cub. yds. ballast, ...			at $0 25	3,750 00
Paving at west end of Green River Bridge, &c., ...				400 00
Repairing present culverts, ...				300 00
Alteration of town roads, Hawkes' Ravine, &c., ...				1,000 00
Crossings and cattle guards, ...				900 00
Land damages, including depot lands, also land for emb. at Green River, ...				8,000 00
Fencing 3,800 rods, ...			at $1 10	4,180 00
Laying 3 miles of track, including $\frac{2}{3}$ mile for sidings and turnouts,			at $500	1,500 00
				$123,042 20

To build stone arches over the Green River and public road, and make a solid embankment across the valley, would add about $35,000 to the above.

From Bardwell's Ferry to Shelburne Falls.—Length, 5.42 *miles.*

2,000 cub. yds. grading for depot at Shelburne Falls.
97,054 " " filling trestle work and completing cuttings and embankments.

99,054 cub. yds. earth, ...	at	$0 20	$19,810 80
720 " " solid rock, ...	"	1 20	864 00
250 " " loose rock, ...	"	0 50	125 00
Carried forward,			$20,799 80

		Brought forward,		$20,799 80
611	cub. yds.	box culverts and drains,	at $3 00	1,833 00
104	" "	arch culverts, ...	" 4 50	468 00
2,893	" "	bank wall, ...	" 2 00	5,786 00
1,200	" "	rip-rap, ...	" 0 80	960 00
2,870	" "	river-bridge masonry, .	" 8 00	22,960 00
	Foundations of masonry, ...			1,800 00
560	feet bridge superstructure (Deerfield and Bear Rivers), ...		at $24 00	13,440 00
14,000	cub. yds.	ballast, ...	" 0 25	3,500 00
	Repairing present culverts and drains, ...			500 00
	Alteration of town roads, ...			500 00
	Crossings and cattle guards, ...			600 00
	Land damages, including depot lands at Shelburne Falls, ...			1,500 00
	Fencing 2,100 rods, ...		at $1 10	2,310 00
	Laying $5\frac{1}{2}$ miles railway track, .		" $500	2,750 00
				$79,706 80

From Shelburne Falls to Tunnel.—*Length*, 17.02 *miles.*

78,194 cub. yds. in reducing slopes.
201,476 " " additional, to complete cuttings and embankments.

279,670
100,000 deduct embankment to be formed from material excavated from tunnel.

179,670	cub. yds.	of earth, ...	at $0 20	$35,934 00
13,908	" "	solid rock, ...	" 1 10	15,298 80
1,500	" "	loose rock, ...	" 50	750 00
1,311	" "	box culverts and drains,	" 3 00	3,933 00
420	" "	arch culverts, . . .	" 4 50	1,890 00
3,127	" "	bank walls, . . .	" 2 00	6,254 00
5,100	" "	rip-rap, ...	" 0 80	4,080 00
3,710	" "	river-bridge masonry,	" 8 00	29,680 00
1,165	" "	road-bridge masonry,	" 4 00	4,660 00
1,478	" "	small brook bridges,	" 4 00	5,912 00
		Carried forward,		$108,391 80

		Brought forward,	$108,391 80
	Foundations of masonry, ...		3,000 00
700	feet of river-bridge superstructure (includes two bridges over the Deerfield; Clesson's, and Chickley Rivers), ...	at $22 00	15,400 00
210	feet of road and brook bridges,	" 8 00	1,680 00
44,000	cub. yds. ballast	" 25	11,000 00
	Enlarging and repairing present culverts, ...		2,000 00
	Alteration of town roads, ...		7,000 00
	Crossings and cattle guards, ...		2,400 00
	Land damages, ...		25,000 00
	Fencing 7,300 rods, ...	at $1 10	8,030 00
	Laying 17½ miles of railway track (including ½ mile for turnouts and sidings), ...	" $500	8,750 00
			$192,651 80

SUMMARY OF COST FROM GREENFIELD TO EAST END OF TUNNEL.

From Greenfield to Bardwell's Ferry, . . .	$123,042 20
" Bardwell's Ferry to Shelburne Falls, .	79,706 80
" Shelburne Falls to Tunnel, ...	192,651 80
Total for grading, masonry, bridging, land damages, and fencing, ...	$395,400 80

To the above estimate has to be added the following items of materials for the superstructure not delivered.*

Carried forward, $395,400 80

* MATERIAL.	Total required.	Now delivered.	Wanting.
2,250 cross-ties per mile × 31½ miles, . .	70,875	31,000	39,875
Iron rails, 58 lbs. per yard, . 2,871 tons, Chairs and spikes, ... 150 "	3,021 tons.	2,723 tons.	298 tons.

	Brought forward,		$395,400 80
39,875 cross-ties,		$10,710 00	
298 tons of iron,	" 60	17,880 00	
		$28,590 00	
Less value of bridge and other material on hand,		4,000 00	
			24,590 00

Locomotive Engines and Cars.

3 locomotive engines,	$27,000 00	
6 passenger and 40 freight and baggage cars,	25,000 00	
12 ballast cars,	3,000 00	
		55,000 00

Depot Buildings and Fixtures.

Passenger and freight house at Greenfield,	$3,000 00	
Engine houses and wood sheds,	3,000 00	
Way stations (including water),	8,000 00	
Turntables and miscellaneous,	6,000 00	
		20,000 00
Contingencies including management and engineering,		25,000 00
	Total,	$519,990 80

The above estimate I consider sufficient to complete the road from Greenfield to the Tunnel in a substantial manner, filling the present trestle work, and replacing the present bridges with others of greater strength and of approved and tried construction. I would consider it unnecessary, however, to make the whole expenditure before bringing the road into use. Some of the slopes may for the present be allowed to remain at less than $1\frac{1}{2}$ to 1, and some of the trestle work may also be made serviceable for some time. Some $50,000 may be thus saved on present outlay without materially affecting the character or the eventual cost of the road.

DEERFIELD ROUTE.

This line leaves the Vermont & Massachusetts Railroad $1\frac{1}{3}$ miles east of the present junction with the Troy & Greenfield Railroad, and keeping on the south side of the Deerfield River, crosses the Connecticut River Railroad, on a level, 800 feet south of the Cheapside Bridge over the Deerfield; thence runs nearly parallel with that road to Deerfield Centre, passing about 20 rods east of the academy; thence passing in the rear of the village lots, and curving to the west on the meadows, crosses the Deerfield River at Martin's Falls, about one mile below Stillwater Bridge, and at an elevation of 28 feet above ordinary water; thence follows up the northerly side of the river to Bardwell's Ferry, where it unites with the present road.

In crossing the Deerfield meadows, the grade has been placed about 8 feet above freshet level, and a long and heavy embankment is required. The only other work of any magnitude, is at the sharp bend of the river above Stillwater. Here, either a deep rock cutting must be made, or two bridges built over the Deerfield to obtain a curve of 955 feet radius. Both lines shown on the map were surveyed. The estimate has been made on that keeping on the northern side of the river.

The whole length of the line from the Vermont & Massachusetts Railroad to Bardwell's, is 8.11 miles. It has 489 degress less curvature, 150 feet less rise and fall, and reduces the maximum grade on the Troy & Greenfield Railroad ascending west, from 58.6 to 50.16 feet per mile. The maximum in the opposite direction occurs between North Adams and the tunnel, and of course is not affected by this line. The length of the through route is reduced by this line $\frac{92}{100}$ of a mile.

The following is the estimate of cost for preparing the road bed for the superstructure: —

Length, 8.11 *Miles.*

254,600	cub. yds. of earth including 10,000 for grading depot, ...	at $0 19	$48,374 00
82,000	cub. yds. solid rock, ...	" 1 10	90,200 00
5,000	" " loose rock, ...	" 0 50	2,500 00
947	" " box culverts and drains,	" 3 00	2,841 00
2,484	" " arch culverts, . . .	" 4 50	11,178 00
		Carried forward,	$155,093 00

	Brought forward,		$155,093 00
500	cub. yds. bank walls, . . .	at $2 00	1,000 00
1,200	" " rip-rap, ...	" 0 80	960 00
1,120	" " road-bridge masonry, .	" 4 00	4,480 00
1,470	" " river " " . .	" 8 00	11,760 00
	Foundations of masonry, ...		1,500 00
370	feet superstructure of Deerfield River Bridge, ...	at $24 00	8,880 00
100	ft. superstructure of road bridges,	" 8 00	800 00
21,000	cub. yds. of ballast, ...	" 0 25	5,250 00
	Alteration of town roads, ...		750 00
	Farm crossings and cattle guards, . .		1,000 00
	Land damages, including depot lands, .		17,500 00
	Fencing 3,700 rods, . . .	at $1 10	4,070 00
	Laying $8\frac{3}{4}$ miles of track, including $\frac{2}{3}$ mile for sidings and turnouts . .	at $500	4,375 00
			$217,418 00
	To the above estimate there should be added $\frac{4}{10}$ of a mile of railway superstructure, being the increased length of road required to be constructed on this line by the Troy & Greenfield Railroad — say, at $9,000 per mile, ...		3,600 00
	Total, ...		$221,018 00
	To complete the grading, masonry, and bridging on the present location, from Greenfield to the point of junction at Bardwell's, is estimated to cost, . .		$123,042 20
	Making a difference in favor of the present road of, ...		$97,975 80

If stone arches and an embankment should be adopted at the crossing of the Green River on the present location, the difference in cost would be reduced to about $63,000.

The Deerfield route is unquestionably much superior to the present road as a through line, but it will not accommodate Greenfield, nor the local business of the Deerfield valley with that town, so well. The nearest suitable place for a depot is two thirds of a mile further from

the village than the present junction. It would, however, better accommodate Deerfield Centre and Mill Village.

It would be perfectly practicable to cross the Deerfield River and unite with the Vermont & Massachusetts Railroad at the trap ledge, about 1,700 feet below the Cheapside Bridge. This would bring the point of junction 3,000 feet nearer to Greenfield, but the building of a bridge would cost considerably more than the building of this length of additional road.

If the Deerfield route is adopted, the only way Greenfield could be properly accommodated would be by running cars by horse or steam power on the Vermont & Massachusetts, or Connecticut River Railroads, to connect with the several trains.

Its adoption now involves the abandonment of $7\frac{7}{10}$ miles of the present road.

Viewed as a through line, the saving of nearly a mile in distance, 489 degrees of curvature, the reduction of the maximum grade, and the avoidance of the Green River Bridge, with its sharp curve, would be of considerable importance.

The following table exhibits the leading characteristics of both lines, from the points of common junction on the Vermont & Massachusetts Railroad, and at Bardwell's Ferry: —

STATEMENT.	By Greenfield.	By Deerfield.	Difference.
Length,	9.03 miles.	8.11 miles.	0.92 miles.
Total curvature,	1,274 deg.	785 deg.	489 deg.
Least radius of curvature,	716.2 feet.	955 feet.	238.8 feet.
Whole number of curves,	42	22	20
Number of curves of 955 feet radius,	20	2	18
" " " under 955 feet radius,	6	0	6
Maximum grade east,	38.72 feet.	28.6 feet.	10.12 feet.
" " west,	58.63 feet.	34.52 feet.	24.11 feet.
Total rise going east,	164 feet.	89 feet.	75 feet.
" " " west,	110.8 feet.	35.8 feet.	75 feet.
Total rise and fall,	274.8 feet.	124.8 feet.	150 feet.
Estimated cost to complete road ready for superstructure,	$123,042 20	$221,018 00	$97,975 00

(For details, see Tables Nos. 5 and 6.)

TUNNEL.

"The completion of the tunnel is unquestionably the key of the whole enterprise."

The Hoosac Mountain, which forms the barrier to be perforated, is a portion of the Green Mountain range, which extends from the borders of Canada to those of Connecticut. In the vicinity of the proposed tunnel, and for a distance of several miles on either side, its summit presents almost an unbroken ridge, elevated about 2,500 feet above tide water. Its geological character is primitive, being composed mainly of mica and talcose slate, and sometimes approaching to the character of gneiss, except at the foot of the western slope, where there is a secondary formation, which overlays that of the mountain, and through which the tunnel must be excavated for about ½ a mile. This is composed, so far as penetrated, of a hard silicious rock, quartzoze sandstone, and some limestone, much displaced and broken up; the whole overlaid with gravel, clay, and sand, and full of water, accumulated from the slope of the mountain.

On the eastern side, the stratification is inclined at an angle of about 20° from the vertical, the dip being to the east, while on the western side the inclination is in the opposite direction, and at an angle of about 30° from the horizon.

In order to determine the character of the rock intermediate, and also its dip and bearing, examinations were made on the line of the tunnel, and specimens collected. These specimens have been arranged on a section or model of the mountain, herewith submitted, and show marked uniformity of structure, except those from the western end.

The following table gives the inclination, direction of dip, and line of bearing of the stratification, as determined at the surface, and also inside of the tunnel, so far as constructed. The course of the tunnel is N. 81° 8′ W. from the eastern end, and S. 81° 34′ E. from the western end. A slight angle being made at the centre, the object of which is more certainly to make the different workings unite.

TABLE.

Number of Station.	Distance from east end of Tunnel in Miles.	Inclination of Strata from horizontal.	Direction of Dip.	Line of Bearing.	LOCALITY.
1590.84	0.000	70°	East.	N. 8° E.	East end of Tunnel.
1594	0.060	75°	"	N. 10° E.	Inside of Tunnel.
1597	0.117	75°	"	N. 5° E.	" "
1601	0.192	60°	"	N. 8° E.	" "
1605	0.268	62°	"	N. 10° E.	" "
1609	0.344	65°	"	N. 8° E.	" "
1614.53	0.449	55°	"	N. 10° E.	" "
1600	0.174	73°	"	North.	Outside of Tunnel, 80 rods S. of station 1600.
1610	0.364	75°	"	North.	" " on line.
1612	0.401	75°	"	North.	" " "
1613	0.420	80°	"	N. 20° W.	" " "
1620	0.552	72°	"	N. 20° E.	" " "
1640	0.931	60°	"	N. 10° E.	" " "
1652	1.158	60°	"	N. 20° E.	East Summit.
1660	1.310	55°	"	N. 10° E.	1000 feet North of line.
1675	1.594	48°	"	N. 15° E.	East Branch, Cold River.
1692	1.916	36°	"	N. 10° E.	250 ft. S. of line in main branch of Cold River.
1706	2.181	28°	"	N. 20° E.	1500 ft. N. " " " " " "
1723	2.503	22°	"	N. 20° E.	3000 ft. N. " " " " " "
1728	2.598	29°	"	N. 5° E.	2000 feet North of line.
1738	2.787	anticlin	al axis	North.	2700 " " "
1744	2.901	30°	West.	N. 15° E.	1500 feet South of line.
1758	3.166	20°	"	N. 5° E.	3300 feet North of line.
1768	3.355	28°	"	N. 5° W.	800 feet South of line.
1780	3.583	32°	"	N. 5° E.	West Summit, 600 feet North of line.
1790	3.771	28°	"	North.	700 feet South of line.
1846.58	4.844	22°	"	N. 5° E.	West end of Tunnel.

The disadvantages under which tunnelling operations proceed arise from want of space, light, pure air, the penetration of water, necessity of securing or removing loose fragments, and the inconvenient communication and means of removing the material. The time required and the cost of completion are dependent on the character of the material, quantity of water, number and depth of shafts ; whether arching is required, use of machinery, and the skill and good management displayed by the engineer and contractors in meeting and overcoming difficulties.

The cost of tunnels through rock is altogether more certain than when through earth, clay, sand, or any other loose material; and when the rock is of a character to require no arching, the cost is generally less.

Heretofore tunnels have been excavated mainly by hand labor, and from the small space which they afford to operate in, the number of men that can be employed is limited, and the operation slow and tedious. The progress that can be made with the *heading*, through rock, determines the progress of the whole work. The bottom excavation, from the larger force that can be worked on it, can always be taken out as fast as the heading can advance. To expedite works of this kind, where the tunnel is at no great depth below the surface, shafts are generally sunk, which, by increasing the number of faces that can be operated upon, allow more men to be employed. In the Hoosac Tunnel, however, from the great height which the mountain rises above the level of the railroad, this is not practicable, except for a short distance at the western end, and in the valley or depression of the mountain, nearly midway between the ends.

TUNNELLING MACHINES.

Various attempts have been made to reduce the cost and expedite the work of tunnelling, by using machinery driven by steam or other power. When the tunnel under the Alps was first projected, a boring machine was proposed to be used, which, it was anticipated, would reduce the time to less than one tenth of that which would be necessary by the ordinary and common methods previously practised. The Civil Engineer and Architect's Journal of 1847 contained the following account of it, headed, "Tunnelling the Alps."

"The Moniteur Belgé announces that experiments have been made in order to test the efficacy of a machine, just invented, for the purpose of effecting a new and speedy method of boring tunnels. It is proposed to apply this machine to the construction of the great tunnel about to be commenced in connection with one of the Italian lines.

It was placed in front of the web, and effected a bore to the depth of seven inches in thirty-five minutes. At this rate, the new invention will complete upwards of 16½ feet of bore per day; and the proposed tunnel through Mont Cenis will be finished in the space of three years. The experiments have been repeated twice before the first engineers of France, and with the *most complete success*."

This machine, it would appear, was abandoned, as the work, when commenced some ten years later, was prosecuted by hand labor, and is now in progress by the use of power drills.

Shortly after the Troy & Greenfield Railroad was chartered, and when there was some prospect of the tunnel being prosecuted, the attention of inventors and mechanics was directed to the subject of tunnelling machines. One was constructed at South Boston in 1851, specially with reference to, and intended to be used at, the Hoosac. This machine weighed about seventy tons, and was designed to cut out a groove around the circumference of the tunnel 13 inches wide and 24 feet in diameter, by means of a set of revolving cutters. When this groove had been cut to a proper depth, the machine was to be run back on its railway, and the centre core blasted out by gunpowder, or split off by means of wedges. It was conveyed to the Hoosac, and, the approach not being then completed, was put in operation on a vertical face of rock near the proposed entrance of the tunnel. In the report of the Railroad Committee, to whom was referred the petition of the Troy & Greenfield Railroad Company for State aid, in 1853 (H. Doc. No.), the following account is given of its performance: —

"Wed., March 16th, 1853. — After a careful survey of the machine by the Committee, to become familiar with its structure, it was set in operation, and run fifteen minutes, when it was found, by measurement, to have cut into the rock *four and one eighth inches*, or at the rate of 16½ inches per hour. The weather was very cold, and both the machine and the rock were filled with frost; consequently, the operators did not dare to test the machine to the extent of its capacity. Under more favorable conditions, it had cut *twenty* inches, or more, per hour. The operations of the machine seemed to give great satisfaction to all who witnessed them."

Twenty inches per hour is at the rate of 20 feet in twelve hours, and were it practicable to have continued the machine in operation for this length of time daily, the completion of the tunnel, by operating at both ends, would have been effected in less than two years.

The whole length perforated by this machine during the various

trials made with it was about 10 feet. Shortly after the visit of the Committee, however, further experiments were abandoned; and last year it was broken up (having been sold as old iron), except the main shaft, which still remains at the eastern end of the tunnel.

About the same time another machine was constructed at Hartford, known as the "Talbot Tunnelling Machine." The principle of this was by means of revolving cutters, fixed on arms, to cut out the whole area of the tunnel. The machine was adapted to cut 17 feet in diameter, and weighed, exclusive of the steam engine and boilers employed to operate it, about sixty tons.

The cutters were rotating disks of steel, with their edges properly adapted to cut away the surface of the rock by rolling against it. Sets, or series, of these rotating disks were applied to the surface of the rock, in such a manner that they described, in their action, a segment of a circle from the centre to the circumference of the tunnel to be excavated, in combination with a slow motion around said centres; while, at the same time, the entire machine which carried the cutters advanced forward in the direction of the axis of the tunnel. Machinery was also to be applied to removing the material excavated from the front, and deposit it in cars in the rear of the machine. I witnessed several trials of this machine on gneiss rock, near Harlem. Its greatest progress was 2½ inches in 15 minutes, or at the rate of 10 feet in 12 hours. Several attempts were made to run it continuously for 24 hours, but in the aggregate it never accomplished more than could be done by hand labor. The company who constructed and owned it intended to devote themselves to excavating tunnels, and obtained a contract on a railroad in New Jersey. They operated the machine for several weeks, but the progress made not proving satisfactory, it was removed, and the work completed by hand labor.

A third machine was constructed in New York, intended, like that constructed at Hartford, to cut out the whole area without blasting. It was adapted to excavate the heading only, or a hole eight feet in diameter, which was afterwards to be enlarged by manual labor and blasting. This machine was put in position at the western end of the tunnel; and Mr. Haupt, in his published address at a public meeting at the American House, Boston, June 9, 1857, made the following remarks in regard to it: —

"It will naturally be expected that I should say something on the subject of the boring machine. I can only say that I believe it will be successful. It will be put together and in working order in from four to six weeks. Its principle of action is different from any of its

predecessors, and far more likely to succeed. The only similar machine in existence has recently been tried in California, where it cut a six foot hole in hard rock at the rate of 23 inches in an hour and 45 minutes, or at the rate of 26 feet per day, with one machine."

And, in a published letter to General Wool, under date of September 25, 1858, Mr. Haupt says: "The slowest progress of the machine, when working, will be fifteen inches per hour; the fastest, twenty-four inches. A machine at each end, working but half the time, with the slowest feed, should go through the mountain in twenty-six months."

This machine, which weighed about 50 tons, and which Mr. Haupt states cost his firm $25,000, was put in operation at the western end of the tunnel, but proved an entire failure. It never excavated a single foot of tunnel, but, after various trials, was dismantled, raised up from the road bed so that cars could pass under it, and now remains at the western portal to the Hoosac, a monument of misapplied ingenuity.

Boring and tunnelling machines, therefore, in this country appear so far to have failed to meet the expectations of their projectors.

In England, various attempts have also been made at tunnelling machines. In 1857, Captain Pennice, of the royal engineers, constructed one on a small scale, and it was stated that the Worcester & Hereford Railway Company had ordered one to cut a tunnel 13 feet in diameter through the Malvern Hills, which are composed of sienite, and that another was to be set at work upon the great Hauenstein Tunnel, through the Jura Mountains. The following is a description of the machine:—

"This machine consists of a species of steam battering-ram, or immense piston-rod, at the head of which a powerful wrought-iron cross is fixed, consisting of four, eight, sixteen, or twenty-four arms. These arms are completely studded with diamond-shaped steel points, and, by an ingenious contrivance, at every blow on the face of the rock a part of the revolution of the cross is made; thus imitating the action of the boring tool in preparing for a blast.

"The line of diamond-head chisels on each arm is thus kept continually cutting near an edge of rock, which is much more advantageous than a blow in the centre of a solid. The diameter of the excavation made is such as to include the whole of the machinery, which is on a wheel-truck lying on the rails, and progressively follows its excavator. The progress is something like that of the Teredo Navallis, which is supposed to bore, with its horny head, a hole large enough for the body to follow. The difficulty with a machine of this nature is, to temper the blow to the hardness of the rock which is to be cut, until

the steel points will bear the reaction; accordingly, this is very cleverly done in the machine, by an arrangement similar to the steam-hammer of Mr. Nasmyth; and in very hard rock, a speed of 200 blows to a minute, with a very short stroke, can be given. Ventilation is very well managed by the action of the waste steam, which is driven into a wooden conduit pipe, causing a strong current at the eduction near the mouth of the tunnel, and a consequent vacuum and return current within.

"The experimental machine was made with a ram five feet in diameter, and it cut its way in sandstone, at Newcastle, at the rate of 20 inches per hour, to a length of 80 feet, when it became clogged, for want of proper arrangements to remove the chippings. This is now proposed to be done by means of something like a dredging ladder, which will cast back the material under the wheels of the engine, whence it can be taken away on trucks."

Satisfactory as this account appears, I am not aware that any machine, on this plan, has been actually applied to the construction of a tunnel. Last year there were some notices of a new tunnelling machine on "Roberts' patent," constructing by Hawks, Crawshay & Co., London, weighing fifty tons, and to be operated by steam, intended to cut from 11 to 30 feet diameter; but I have seen no account of its completion or trial.

Had either of these machines proved successful, we would, no doubt, have had full details of their performance.

POWER DRILLS.

Mr. Edwards proposed to use power drills in excavating the tunnel, and based his estimate of the time required on their being adapted to tunnelling. They have frequently been tried on public works for the last twenty years, but have never come into general use. Where the rock is favorable they expedite the work, but there is a general impression among contractors that there is not much economy in using them. In an open cutting, however, there are various ways of expediting the work which cannot be adopted in a tunnel, and as the greatest attainable progress, irrespective of mere cost, is all important in the latter, power drills, it may reasonably be expected, may be applied to better advantage.

In the construction of the Mont Cenis Tunnel, which has been in progress for several years, machinery for drilling has lately been successfully introduced. The drills, or perforators, are operated by com-

pressed air, and the rate of progress by their use has been increased from about 50 feet per month, by hand labor, to 130 feet on each face.

As this is the only tunnel in which machinery has been successfully used, it is important to examine whether the same means cannot be applied at the Hoosac.

The project of connecting the French and Italian lines of railway by the Mont Cenis was proposed more than fifteen years since, but the work was not actually commenced until 1857. The government of Victor Emanuel is at the cost of the work. The tunnel is $12\frac{1}{2}$ kilometres, or about $7\frac{6}{10}$ English miles in length, and, in many respects, has a marked resemblance to the Hoosac Tunnel. The following account of it, from the London Journal of the Society of Arts, I deem of sufficient interest to quote entire: —

"TUNNEL THROUGH THE ALPS.

"A communication on this subject has recently been made to the French Academy of Sciences by M. Menebrea, and published in the Comptes Rendus, stating that several months ago the immense work of boring a tunnel under the Alps, between Modane and Bardonnèche, was commenced. These places are situated on opposite sides of the Alpine chain which divides Piedmont from France, at a point where the valleys of the Arc and Doire are almost parallel to each other, and here they are on the same level, the mountain being most narrow at this spot. This important position had been noticed about twenty years ago by M. Medoil, and had often attracted the attention of engineers and geologists. The tunnel will be $12\frac{1}{2}$ kilometres in length, and is designed in the same vertical plane, but, to facilitate drainage, is somewhat higher in the middle than at the extremities, so as to form a slope on each side, one being an inclination of five in a thousand and the other being twenty-three in a thousand, in consequence of a difference of level between the two extremities; the height being, Bardonnèche (southern orifice), 1,324 metres; highest point, 1,335 metres; Modane (northern orifice), 1,190 metres above the level of the sea. The crest of the mountain being 1,600 metres higher than the highest point of the tunnel, the sinking of shafts is practically impossible; hence the tunnel could only be worked at its extremities, so that it was calculated that the labor by the ordinary processes could not be completed in less than 36 years. The difficulty of ventilation was also very great. The mountain, having been examined geologically by MM. Elie de Beaumont and Angelo Sismonda, was found to contain micaceous sandstone, micaceous schists, quartzite, gypsum,

and limestone; of these various kinds of rock, the quartzite alone would be likely to offer any serious resistance to engineering operations, but the stratum of this appeared not likely to be very thick. The plan proposed for overcoming the difficulties was put forward by three Sardinian engineers, MM. Sommeiller, Grattone, and Grandis, who proposed to turn the abundance of water, for which the locality was remarkable, to account, by applying it to a peculiar system of perforation and ventilation.

"The first apparatus designed by these gentlemen consists in a hydraulic air condenser, which is a syphon, turned with its orifices upwards, and communicating by one of them with a stream of water, and by the other with a reservoir of air. The water descending into the first branch enters the second, and by the pressure it exercises condenses the air, which is then forced into the reservoir. When the pressure of air arrives at a certain point, a valve is opened, by which the water contained in the syphon is let out, and the operation recommences. The emission and introduction valves are regulated by a small machine, operating by means of a column of water, and the air in the reservoir is maintained at a constant degree of pressure by a column of water communicating with another reservoir above. This condensed air is used both as a motive power and for ventilation.

"Commissioners were appointed by the Sardinian government, of which the author of this paper was one, to investigate the efficacy of this plan. Their experiments were made with two kinds of perforators, worked by condensed air instead of steam, one invented by Mr. Bartlett, the other by M. Sommeiller; it is stated that by means of these, holes for blasting may be bored through the hardest sienite in one twelfth of the time which would be required if ordinary means were employed. The perforators may have another advantage; in a space where three couples of miners could hardly be placed, 18 perforators may be set to work; so that by means of these contrivances, it is said that the perforation of the tunnel may be effected in six years, instead of 36, as the inventors calculate upon advancing three metres per day on each side of the mountain, or six metres per day in all. It is calculated that it will require 85,924 cubic metres of air per 24 hours, to replace that which has been vitiated by respiration, torches, and gunpowder at each end of the tunnel, which is equivalent to 14,320 cubic metres of air, condensed to six atmospheres. As the quantity of air necessary to put in action the perforating machines will be only 667 cubic metres at the pressure of six atmospheres, a large portion of the compressed air will thus be available for ventila-

tion. Both on the side of Bardonnèche, and on that of Modane, it is said that water power exists, which is abundantly sufficient for the required purpose. Whenever this great work is finished, it is calculated that the journey from Paris to Turin will only occupy 22 hours, and from Paris to Milan, only 27 hours. The author is of opinion that great credit is due to the Sardinian government for the liberal and judicious manner in which it has encouraged this great and important work."

The above account was written before much progress had been made in the actual construction of the tunnel, and the plans were subsequently modified to some extent. As the latest information on the subject within my reach, I submit the following extract from an article in the Civil Engineer and Architect's Journal, of October last, which, although evidently containing some blunders, gives a very intelligible account of the machinery used and progress making: —

"This stupendous work was begun on the 31st August, 1857. At the present moment the excavations extend to 740 metres (2,427 feet) on the north, and to 950 metres (3,116 feet) on the south side, and consequently 10,530 metres (34,538 feet = 6.54 miles) are yet to be bored. Up to a late period, the mining operations were performed by the ordinary method of manual labor, but new boring apparatus has been adopted on both sides of the tunnel, and the work progresses daily at the rate of four or five feet at each end. Still, it is evident that ten years will hardly suffice to complete the work. The cost of this gigantic undertaking is estimated at sixty millions of francs, but probably this sum will be much exceeded. France has to contribute twelve millions of francs, but has not done so hitherto. If present circumstances continue, it is to be feared the works will be stopped.

"The work of boring is done by machines, which are moved by air compressed by hydraulic pressure. The water necessary for this purpose is obtained in the following way: The water which constantly pours down the slopes of the Alps, and which forms the chief supply of the little river of Bardonnèche, is collected in channels and large reservoirs, and thence conducted by large tubes to a building in which there are ten iron tanks in the shape of steam boilers, each of which is furnished with a vertical tube of two feet diameter and fifty metres (164 feet) high. While the water is conducted from the main tube into these ten secondary ones, the air is conducted by a ventail apparatus, of which each tube has one. The air and water is so conducted that the tanks are completely filled with air, and the tubes with water. The columns of water in the tubes now compress the air with a

force of 22,000 pounds, which causes the air to issue from the reservoir with great force. A strong metallic tube eight or nine inches wide is conducted into the tunnel, close to the boring apparatus, where four tubes of india rubber, secured by screws, bring it in four cylinders placed horizontally, from whence the rotary apparatus, which moves the boring instrument, is fed. This rotary apparatus moves eight steel gimlets, each three feet long, which, placed at an angle of 45°, penetrate, pushing and boring into the rock. As the borers make 200 strokes each minute, the noise is terrible. The air cylinder, the borer, and the men at work, are placed on an iron framework, which can be moved upon wheels rolling on iron rails. Ventilation as well as the removal of dust is effected by the opening of spiral air-valves fixed on the iron tubes.

"The boring apparatus made at the manufactory of Cockerill, at Sèraing, are 9 feet long by 10 to 12 inches high. Each machine perforates the rock, according to its solidity, to the depth of 2 feet, and a width of 1½ inches. On each surface of 6 square metres, four holes, 2 feet long and 3 inches wide, and 70 or 80 holes of the same length, but of less width, are made. After all the holes have been drilled, which generally occupies six hours, the iron framework, with the boring apparatus, is drawn backward in the shaft about 100 metres, and it is closed by a strong wooden gate, for avoiding the projection of stones when the mine is exploded. The method resorted to here is the usual one of gunpowder and a conducting train, but the 4 large holes in the middle are not loaded. After the firing of the mine the smoke of gunpowder is expelled by means of the ventilating apparatus, and the debris of rocks carried in small carts, on a lateral rail, to the large wagons at the entrance of the tunnel, and thence conveyed to the general repository of rock debris. The collecting and removing of the rock debris takes also six hours, and thus the blasting can only be done twice a day. There are two rails in the tunnel, between which is a conduit for the efflux of the water. It is altogether supported by a vault; that at the north end made of hewn stones; on the south side, of bricks. Outside are reservoirs and the building for the machines to compress the air, a mechanical workshop furnished with a turbine, a large building for the officers, and a manufactory of gas for lighting the tunnel and the buildings."

The progress of four to five feet per day, which is here represented as being now made at Mont Cenis, is more than has been accomplished by hand labor, or by any apparatus yet put to the practical test of actual tunnelling. I know of no reason why the same kind of

machinery could not be adopted at the Hoosac, and be equally as successful. They may have the advantage of a greater amount of skilled labor, and at cheaper rates, but this would be fully offset by the greater mechanical ingenuity and the labor-saving expedients which would be adopted in this country. Water power is there used at both ends of the tunnel, and the same motive power may be used at the eastern end of the Hoosac. A dam across the Deerfield would furnish the requisite power. At the western end a sufficiency of water is not to be obtained, and steam would have to be resorted to, but the difference in expense could not be very great.

From the description given of the rock at Mont Cenis, I should judge that a considerable portion of it will be easier to work than mica and talcose slate, while another portion will be much harder than any yet encountered at the Hoosac. Taking into account, however, that the Mont Cenis Tunnel has to be lined, and the delays and interruptions in consequence, I am disposed to think that the difference in the rate of progress would not be material. I will, therefore, submit estimates based on hand labor, and also on using machinery similar to that at Mont Cenis.

SIZE OF TUNNEL.

As originally proposed, the tunnel had sufficient size for two railroad tracks, $24 \times 20\frac{1}{2}$ feet, but the Loan Act of 1854 specified that it might be built for "one or more." In 1856 the Railroad Company contracted with Haupt & Co. that they might build it for a single track; and in 1859 the legislature authorized it to be excavated 14 feet wide by 18 feet in height.

There are many serious objections to a single track tunnel of the length proposed, and especially on a road intended for a great through line. Embarrassing delays must frequently occur; any interruption or break down in passing through it would be attended with great inconvenience and danger. The smoke and steam from the locomotive engine, when at rest, would soon fill a portion of the tunnel; and in case of the locomotive and cars getting off the track, they would occupy the whole space, and be difficult of removal; even to make communication from one end of the train to the other would be very difficult.

In England, as in this country, the general rule has been to make railroad tunnels of sufficient size for two tracks. The few exceptions have been regretted afterwards, and in England they have generally been enlarged at a greatly increased cost. In a double track tunnel

there is more room for the smoke and steam, and ventilation is better. The additional cost, if the tunnel is made of sufficient size in the first instance, is not great; probably not more than 25 to 30 per cent. The larger the area of the tunnel the less will be the cost per cubic yard for excavation. The heading, which is the most expensive portion, is common to both; draining and ventilation are also common. If the tunnel is arched, and afterwards enlarged, the whole of the arching has to be removed.

The following items of cost of the Bleechingly Tunnel will show how small a percentage of the whole the mere excavation forms: — *

Materials: brick, cement, timber, etc., ...	£61,911	18	8
Labor on brick work, ...	11,643	12	11
Labor: mining shafts and removing material, . .	3,273	2	8
" " tunnel " " . . .	15,727	7	0
Miscellaneous, ...	2,680	16	6
Total, ...	£95,236	17	9

Being at the rate of £23 16 2 per running foot for the whole tunnel, 3,972 feet in length. The arching and material for propping up amount to 77 per cent. of the whole cost, and the excavation to only 20 per cent.

In the contract with Haupt & Co., $12.00 per foot is specified as the price to be paid for enlarging the tunnel for a double track. If this was a fair estimate, it would cost less if taken out to the proper dimensions in the first instance. I will base the estimates on a tunnel of sufficient size for two railroad tracks.

DRAINAGE OF THE TUNNEL.

So far as it is worked from the ends, with the exception of the 3,000 feet between the present shaft and the western portal, I do not anticipate that there will be much trouble from water. At the east end, the whole quantity running from the 2,400 feet already excavated would pass through a two inch pipe laid down on the grade; and in the shaft at the west end the quantity met with is represented as having been of no great account. The ascending grade from both ends, with a summit in the centre, is favorable for drainage; and even if a large quantity of water was met with it would cause no great inconvenience. The stratification of the

* Simms' Tunnelling.

rock crossing the line of the tunnel nearly at right angles, the springs, in all probability, run in the same direction, and if intercepted, the water from them would find its way down the side ditches to the ends of the tunnel. A pipe 24 inches in diameter laid on the grade would discharge at the rate of 6,250 gallons per minute, and the side ditches can readily be made of sufficient size to pass twice this quantity.

With such portions of the tunnel as may be excavated from shafts, the case will be different; here the whole quantity of water met with will have to be raised by steam power, and from the great depth of the shafts, should any large quantity be encountered, will be very expensive.

The water running in the two branches of Cold River, where they cross the line of the tunnel, was gauged on two several occasions, and found to be as follows: —

DATE.	Gallons per Minute.		
	Main Branch.	East Branch.	Total.
October 29, 1862, ...	6,000	1,500	7,500
November 27, 1862, ...	4,400	1,120	5,520

During the spring freshets there is probably three or four times this quantity. Were the whole to find its way into the tunnel, the expense of pumping it to the surface would be very great. But as it now keeps the surface, although running over a porous gravel bottom with a rapid descent, and there are numerous small springs in the valley, I think these facts indicate some impervious strata underneath. In fact, the mica slate appears in the bed of the stream near the crossing. Although, then, from the displaced stratification which occurs in this quarter I should expect some leakage into the tunnel, I do not think it will be serious. Professor Hitchcock has expressed the opinion that the water would not percolate as low as the grade. Be this as it may, even if the whole water of Cold River reached the tunnel, a conduit could be made which would convey it to the ends.

VENTILATION.

In the early history of railroads much difficulty was anticipated in ventilating tunnels from the steam and smoke of the locomotive engine, which, it was supposed, would be deleterious to the

health of the passengers. In practice little inconvenience has been found to exist, the smoke and steam rising to the roof, and either condensing there, or finding vent at the ends or through the ventilating shafts. Not unfrequently, however, with long trains and in certain states of the atmosphere, the smoke descends so as to be sensibly felt in the rear cars.

If the tunnel is constructed for a double track, I would not anticipate much annoyance from this source. My belief is founded on a personal examination of many of the English tunnels.

During the construction of the work, of course artificial means of ventilation will be necessary to supply the workmen and their lamps with fresh air, and to remove the powder gases. This can be accomplished either by forcing fresh air to the headings through a pipe by means of machinery, or by the same means withdrawing the foul air. Still, in a tunnel of the great length of the Hoosac, with a summit in the middle and the entrances nearly on the same level, there may be doubts whether, with numerous trains passing through it, a speedy and perfect ventilation would be established. Any fears on this point would be overcome by sinking a shaft near the centre. The ventilation could then be regulated, if necessary, by the common expedient in mining regions of keeping a fire burning near the top or bottom of the shaft. There is another and more conclusive reason, however, for sinking a shaft, and that is, in order to expedite the completion of the work and save interest on the money expended. A shaft I consider necessary for this purpose, and would sink it about midway between the present end faces of the tunnel, where the depth is about 1,000 feet.

REMOVING MATERIAL.

The average haul which the material from the tunnel, with a central shaft, will have to be carried, will be less than $1\frac{1}{2}$ miles in the tunnel, and $\frac{3}{4}$ mile outside — and by horse power will cost about 30 cents per cubic yard. That removed from the shaft will cost three or four times as much.

TIME AND COST.

The best data, perhaps, for estimating the cost by hand labor would have been the actual expenditure on the portions already completed; but no reliable information is to be procured on this subject. There are

a few facts, however, as to the progress made, to be derived from the monthly returns to the Governor and Council, which will presently be given. My own experience in tunnelling operations has been trifling, being confined to one of 300 feet in length, 24 by 18 feet, on the Norwich & Worcester Railroad, constructed in 1838, through sienite rock, which was performed by contract for $70 per foot run, and was supposed, at the time, to have cost about $60; and 4 or 5 culvert tunnels on the Troy & Schenectady Railroad, through clay slate and graywacke rock, the longest being about 250 feet, and of the dimensions 6 by 3½ feet, which were excavated for $5 to $6 per foot run. There is, however, a large amount of information to be found in various works on the subject of English tunnels, but the geological formation there is entirely different from that of New England.

The English tunnels are rarely through rock of such a character as to be depended on to form the roof, and arching, as a general rule, is resorted to as necessary and indispensable; while the rock at the Hoosac, where the inclination of the strata approaches the vertical, I consider nearly or quite as reliable as an arch, and therefore this important item of expense will be saved for a considerable portion of the distance. Where the stratification is inclined at an angle of less than 45° from the horizontal, there may be places where arching may be necessary to prevent loose fragments from falling on the track.

The English and other tunnels of which we have the most detailed information, are generally works that were extremely difficult of execution, requiring for their accomplishment all the resources of engineering science. They are also generally of much greater size than is proposed for the Hoosac. This is the case with the Box, Kilsby, Bleechingly, Saltwood, Blaisy, and others; they have obtained prominent notice from the great difficulties encountered in their construction, all of them being more or less through loose material,— clay, quicksand, &c., surcharged with water. The area of the Box Tunnel is more than twice the size proposed for the Hoosac double track. During its construction 4,000,000 gallons of water were pumped out daily. In the Kilsby, 3,000,000 gallons. In other tunnels, where no difficulty was encountered, we have few or no details, but know that the cost was much less.

In the United States about 100 tunnels have been constructed on canals and railways, the longest being nearly two miles in length, but the details of a few only are now accessible. In Table No. 7 will be found a list of nearly 200 tunnels, with such information respecting them as I have been able to collect and condense in tabular form.*

* Not published on account of length.

The portion of the Hoosac Tunnel embraced between the western entrance and the present shaft, a distance of 3,008 feet, will, from all indications, be the most troublesome and expensive. The material consists of gravel, clay, sand, detached beds of quartzose sandstone, some of which is partly decomposed, and limestone. The whole formation is full of springs, and a considerable stream, which may, however, be diverted, crosses the line of the tunnel about 800 feet from its mouth.

The shaft, which is 325 feet in depth, is now full of water and cannot be examined, but I am informed that, with the exception of a few feet near the surface, it was entirely in mica slate. How far this rock may extend westerly at the level of the tunnel cannot be determined from the surface, but in all probability it will be found extending with the slope of the mountain, at least as far as the small hollow about 650 feet west of the shaft. This will leave 2,358 feet through material of the character mentioned. An attempt was made to sink a trial pit about 1,100 feet from the westerly end, but the water came in so rapidly it was discontinued, after penetrating through earth and gravel to a depth of 14 feet.

By raising the grade at this end about 30 feet, which can be accomplished without exceeding the maximum in an easterly direction on other portions of the road, the open cutting may be extended for a distance of 1,158 feet probably cheaper than to tunnel. For a part of the distance it might be advisable to cut a trench down to grade and then arch, and afterwards fill in with the material from the slopes on other portions of the cutting. Some of the material to be excavated will require a flat slope; but as there will be a large amount of rock suitable for rough masonry, in portions of the cutting I would propose to build heavy bank-walls where necessary, and thus save excavating a large amount of material and also the haulage of the rock. I estimate the cost of this open cutting, which will range from 25 to 95 feet in depth, at $100,000. There will then remain 1,850 feet of tunnel to be excavated to reach the present shaft, and 20,166 feet between the shaft and the present heading on the easterly side of the mountain. Of the 1,850 feet, probably about 1,200 feet will require arching, and must be excavated entirely by hand labor and blasting. If the work is resumed, I would urge that it be vigorously prosecuted at this end, so as to complete it as soon as practicable, and save the expense of pumping water and hoisting material from the present shaft, which will have to be done until this portion of the tunnel is made self-draining. It might even be advisable to sink another shaft

near the proposed new portal, where the depth would not be more than 90 or 100 feet.

However bad the material may prove, this part, under proper management, can be completed long before the rest of the tunnel. In the estimates, I will allow three years for its completion. I would advise the sinking of two or three trial pits to determine the character of the material in advance. Until it is known, any estimate on this portion will be quite uncertain. I will therefore put the cost, including lining, at $160 per foot for 1,200 feet, and the remaining 650 feet, or that supposed to be mica slate, at $80 per foot. I will also allow $10,000 for a shaft and machinery. The whole will then amount to $254,000 for 1,850 feet of tunnel, or at the rate of $137.30 per foot. It may cost less, and possibly may cost more.

The entire expenditure heretofore made at this end, of open cutting, and 550 feet of unarched tunnel, will be lost by raising the grade and extending the open cutting. Still, I consider it good economy to do so.

The following statements show the monthly progress made in executing several tunnels: —

MONTHLY PROGRESS AT THE HOOSAC TUNNEL,

As derived from the Returns on file in the State House, Boston, from October 1, 1860, *until the suspension of the Work, July* 1, 1861.

HEADING. Commencing 1,901 Feet from Mouth of Tunnel.		BOTTOMING. Commencing 1,710 Feet from Mouth of Tunnel.	
1860, October 1 to " December 1,	2 months, 131 feet.	1860, October 1 to " December 1,	2 months, 84 feet.
1861, January 1,	58 "	1861, January 1,	47 "
" February 1,	53 "	" February 1,	48 "
" March 1,	43 "	" March 1,	39 "
" April 1,	56 "	" April 1,	50 "
" May 1,	50 "	" May 1,	45 "
" June 1,	57 "	" June 1,	56 "
" July 1,	43 "	" July 1,	43 "
Average progress per month,	54½ feet.	Average progress per month,	46 feet.

KINGWOOD TUNNEL, BALTIMORE & OHIO RAILROAD.

Progress made in driving the Headings, as obtained from the Working Profile.

MONTHS.	PROGRESS MADE PER MONTH.				
	From Western End.	From Eastern end.	From Shaft No. 1.	From Shaft No. 2.	From Shaft No. 3.
9	. . .	. . . .	20 feet E. 20 " W.	. . . .	20 feet E.
10	130 feet.	. . . .	30 " E. 40 " W.	. . . .	20 feet E. 35 " W.
11	110 "	. . . .	25 " E. 35 " W.	35 feet E.	30 " "
12	90 "	. . . .	25 " E. 65 " W.	40 " "	65 " "
13	90 "	30 feet.	55 feet. W.	25 " "	80 " "
14	100 "	70 "	80 " "	50 " "	45 " W. 70 " E.
15	130 "	50 "	100 " "	55 " "	75 " "
16	150 "	65 "	125 " "	120 " "	80 " "
17	90 "	65 "	70 " "	100 " "	50 " "
18	100 "	20 "	40 " "	. . . .	50 " "
19	50 "	. . . .	90 " "		
20	. . .	15 feet.	. . . .	. . . .	65 " "
21	. . .	. . . .	. . . .	. . . .	
22	. . .	. . . .	. . . .	5 mo. 135 ft.	55 " "
23	. . .	. . . .	. . . .	. . . .	70 " "
24	. . .	. . . .	. . . .	. . . .	90 " "
25	. . .	. . . .	. . . .		
26	. . .	. . . .	. . . .	55 W.	
27	. . .	. . . .	. . . .	60 "	25 " "
28	. . .	. . . .	. . . .	60 "	70 " "
29	. . .	. . . .	. . . .	. . . .	2 mo. 215 feet.
	1,040 feet.	315 feet.	820 feet.	735 feet.	1,210 feet.
Av. per month,	104 feet.	45 feet.	$54\frac{2}{3}$ feet.	49 feet.	63.7 feet.

Average from ends, $79\frac{7}{10}$ feet. Average from shafts, 56.43 feet.

CINCINNATI & DAYTON RAILROAD TUNNEL.

The following progress was made for 5 months during its construction, in 1853 : —

North heading, from Apr. 28 to Nov. 20, 368 feet, = ...	53½	feet per month.
South heading, from July 20 to Nov. 20, 268 feet, = ...	65	" " "
Average, ...	59¼	" " "
Heading from shaft No. 1, June 20 to Nov. 20, 336 feet, = ...	67	" " "
Heading from shaft No. 2, June 20 to Nov. 20, 336 feet, = ...	67	" " "
Heading from shaft No. 3, June 20 to Nov. 20, 300 feet, = ...	60	" " "
Average, ...	65	" " "

The engineer, in furnishing this statement to Colonel J. W. Sever, remarks, that "At no time has there been more than half a force employed, and now, only one third of a full force is engaged on its construction, owing, partly, to a scarcity of miners and common laborers, without which it is impossible to proceed with the maximum degree of rapidity. The workings heretofore indicate the practicability of advancing the heading at least 2½ feet in twenty-four hours, or, with operations at eight points, a total of 20 feet in twenty-four hours." And, in a subsequent letter to the same party, he says: —

"During the month of December I succeeded in having full gangs worked in two different headings and one ledge, and the result was, that each of the headings was advanced 89 feet, and the ledge 90 feet."

SUMMARY OF THE FOREGOING, EMBRACING ALSO SEVERAL OTHER TUNNELS.

NAME OF TUNNEL.	Length in Feet.		Progress made per Month in Feet.		MATERIAL.
			From Ends.	From Shafts.	
Hoosac,	. . .	Average for nine months,	$54\frac{1}{2}$	. . .	Mica and talcose slate.
Kingwood,	4,100	From west end 1,040 feet,	104	. . .	
"	"	From east end 315 feet,	45	. . .	Coal, shales, and limestone.
"	"	Average from shafts,	. . .	56.4	
Black Rock,	1,932	Average advance from the two ends,	$40\frac{1}{2}$	. . .	Graywacke slate.
" "	"	Average from shafts,	. . .	33	Graywacke slate.
Pulpit Rock,	1,638	From east end,	47	. . .	Hard blue sandstone, with veins of quartz.
" "	"	From shafts,	. . .	34	
Alleghany Tunnel,	3,750	Average workings,	80	. . .	Coal, shales, &c.
Western and Atl. Railroad Tunnel, Geo.,	1,477	From west end 600 feet,	39	. . .	Clay and sandstone.
" " " " "	"	From east end 847 feet,	59	. . .	Clay and sandstone.
Blue Ridge, Virginia,	4,273	From west end,	$27\frac{3}{4}$	. . .	Blue slate, trap, and quartz.
" " "	"	From east end,	$29\frac{1}{3}$	. . .	Blue slate, trap, and quartz.
Cincinnati,	10,011	Working two shifts,	$53\frac{1}{2}$ to 89	$32\frac{1}{2}$	Marl, clay, and limestone.
Union Canal, Penn.,	. . .	From ends,	36	. . .	Slate rock.
St. Martin's, France,	4,512	. . .	. . .	17 to 56	Red porphyry.
Average of the above,	. . .	. . .	54.2	38	
Mont Cenis,	. . .	By drilling machinery,	120 to 140		

SHAFTS.

Monthly progress in sinking the shafts of the Kingwood Tunnel on the Baltimore & Ohio Railroad, as obtained from the working profile:

Months.	Shaft No. 1.		Shaft No. 2.		Shaft No. 3.	
	Depth of Shaft.	Progress per Month.	Depth of Shaft.	Progress per Month.	Depth of Shaft.	Progress per Month.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1	35	35	21	21	26	26
2	57	22	37	16	37	11
3	85	28	54	17	52	15
4	110	25	86	32	74	22
5	120	10	104	18	74	22
6	120	10	104	18	88	14
7	120	10	144	40	122	34
8	170	50	157	13	165	43
9	173	3	170	13	172	7
Average	per month,	28		21		24

Average for the three shafts, 24⅓ feet per month.

On the Cincinnati & Dayton Railroad Tunnel there are 3 shafts, 199, 194, and 152 feet in depth. They are elliptical in form, 20 by 12 feet, and were sunk at an average rate of 35 feet per month, working *two shifts* in 24 hours, and part of the time short handed.

The following table exhibits the monthly progress: —

Shaft No. 1.		Shaft No. 2.		Shaft No. 3.	
February 1, . . .	20 feet.	February 1, . . .	23 feet.		
March 1, ...	20 "	March 1, ...	17 "		
April 1, ...	37 "	April 1, ...	37 "	April 1, ...	35 feet.
May 1, ...	55 "	May 1, ...	53 "	May 1, ...	35 "
June 1, ...	33 "	June 1, ...	40 "	June 1, ...	38 "
Average, . . .	33 feet.	Average, . . .	34 feet	Average, . . .	36 feet.

Showing that the least month's work was 17 feet, and was when nearest the surface. The greatest month's work was 55 feet. The material in the shafts, with the exception of 12 or 15 feet at the surface, which was yellow clay and soil, was indurated marl with a few layers of stone. The average cost per cubic yard, during April and May, was \$3.10. And the engineer remarks, "There would have been no difficulty in sinking the shafts at the rate of $3\frac{1}{2}$ feet per day of 24 hours (80 feet per month), had they been worked with regularity, full-handed, and systematically, which would have reduced the cost per cubic yard materially, as the expense of engine-men at the mouth of the pit, and foremen, would have been no greater than it was, while more work would have been done."

At the Tamaqua Coal Mines, Pennsylvania, a shaft 10 by 18 feet, and 350 feet in depth, was sunk in 1853–54. The following are the items of cost, when it was down to a depth of 336 feet: —

Engine house and 60-horse power engine and boiler, .	\$6,840 00
Timbering shaft, ...	1,975 00
Cistern in shaft, ...	633 00
Sinking 112 lineal yards, ...	26,605 00
	\$36,053 00

Equal to \$107.15 per foot down. The rock was hard, and difficult to work, being without seams. Some months, a progress was made of 20 and 21 feet working 2 *shifts*, but I am not aware of the average.

A shaft of the Bleechingly Tunnel, $10\frac{1}{2}$ feet diameter, and lined, was sunk at the rate of $3\frac{6}{10}$ feet per day, or 90 feet per month, to a depth of 51 feet. The cost was \$22.81 per foot down.

The shafts of the Blaisy Tunnel are from 328 to $646\frac{1}{2}$ feet in depth, and cost \$46.37 per foot down; progress per month not given. The shafts of the St. Martin's Tunnel, France, averaging about 120 feet in depth, were sunk at the rate of 17 feet per month.

At Magennis Works, near Pottsville, a shaft 14 by 18 feet, when down about 160 feet, is reported in the evidence on the Hoosac Tunnel as having been sunk through rock at the rate of 3 feet in 24 hours, or say 75 feet per month.

A shaft at the Wearmouth Colliery, near Sunderland, was sunk to a depth of 1,578 feet, through various strata of rock, in the course of ten years, or at the rate of $13\frac{15}{100}$ feet per month. This shaft, after being sunk 330 feet, through limestone rocks, tapped a spring, which poured out 3,000 gallons of water per minute, and required a steam engine of 200-horse power to free it.

WELL, FORT REGENT, JERSEY.

In the professional papers of the Corps of Royal Engineers there is a description of this work, which was sunk to a depth of 207 feet through compact sienite rock. The following table shows the progress per month, and the price paid per foot: —

DATE.	No. of Miners. per Month.	Feet Sunk per Month.	Price paid per Foot.	
1806, December, .	14	13	60 livres.	
1807, January, .	12	8½	72 "	
" February, .	12	3	96 "	
" March, . .	12	9	108 "	
" April, . . .	0	0	0 "	
" May, . . .	12	5	120 "	
" June, . . .	12	11	108 "	
" July, . . .	12	8½	108 "	
" August, . .	12	10¼	111 "	Including incidental expenses, the whole cost of the work was about £3,000, or $70 per foot down.
" September, .	12	10	108 "	
" October, . .	12	9¼	108 "	
" November, .	12	9	108 "	
" December, .	12	9	108 "	
1808, January, .	12	9¼	108 "	
" February, .	12	7½	108 "	
" March, . .	12	10¾	108 "	
" April, . . .	12	9	108 "	
" May, . . .	12	12¼	108 "	
" June, . . .	12	13	108 "	
" July, . . .	12	10	108 "	
" August, . .	12	11¾	108 "	
" September, .	12	9¼	108 "	
" October, . .	12	9	108 "	
		207¼ ft.		
Average per month	. . . .	9.4 "		

DEPTH, &c., OF CELEBRATED MINES IN EUROPE AND AMERICA.

(*From Ure's Dictionary.*)

MINES.	Depth of the Principal Shafts.	Quantity of Water per Minute.	Av. annu'l Expense of Drainage.	No. of Men employed
Consolidated and Un. Mines, Cornwall,	1,488 ft.	2 to 3,000 galls.	£12,700	2,500
" " " " "	1,650 "	These mines	are work	ed to a
	depth of	1,370 ft. below	the sea.	
Tresvain Copper Mine, ...	2,180 ft.			
Veta Grande Mines, Mexico, . . .	1,092 "	about 80 galls.	£20,000	900
" " " " . . .	828 "			
Mine of Valenciana, Mexico, . . .	1,860 "	about 110 galls.	£40,000	3,100
Mine of Himmelfurst, Saxony, . . .	1,080 "	50 galls.	. . .	700
Mines of Sweden, ...	1,290 "			
Salt Mines, near Cracow, ...	1,783 "			
Wearmouth Colliery, England, . . .	1,578 "			
Victoria Colliery, Scotland, ...	1,038 "			

The coal pit at Dunkenfield, in Cheshire, England, is 2,004 feet below the surface to the point where it intersects the "Black Mine Coal," a seam that is four feet six inches thick, and of the best quality for domestic and manufacturing purposes. From this point a further depth of 500 feet has been attained by means of an engine plane in the bed of the coal, so that a great portion of the coal is raised from the enormous depth of 2,504 feet.

At Pendleton, near Manchester, coal is daily worked from the depth of 2,505 feet, and the coal of Wiggan is brought from 1,773 feet below the surface. Many of the Durham Collieries are equally deep.

SUMMARY OF PROGRESS MADE IN SINKING SHAFTS.

NAME.	Depth of Shaft.	Feet per Month.	MATERIAL.
	Feet.	Feet.	
Hoosac, ...	325	22	Mica slate.
Kingwood, ...	172	$24\frac{1}{3}$	Coal shales and limestone.
Cincinnati, ...	195	$34\frac{1}{3}$	Marl, clay, and limestone.
Tamaqua, ...	350	20	Hard rock, work'g 2 shifts.
Pottsville, ...	160	75	" " " "
Bleechingly, ...	51	90	Clay and shale.
St. Martin's, ...	70 to 176	$11\frac{3}{4}$ to 20	Red porphyry, 2 shifts.
Wearmouth, ...	1,578	$13\frac{2}{5}$	Limestone, shales, &c.
Fort Regent, ...	207	$9\frac{4}{10}$	Sienite rock.

Average of the above, 32 feet.

It will be observed that there is a considerable difference in the progress made in the several tunnels and shafts. Scarcely any two are alike in character of material, quantity of water, and facilities for working. The Hoosac Tunnel, in my opinion, by working three relays of skilled miners in 24 hours, may be prosecuted from the ends at fully the average of those given, and which nearly coincides with the actual progress made for 9 months in 1860–1. The rock in the main body of the mountain, so far as penetrated, is favorable, and the indications on the surface are, that there will be no material change in its character. If any harder or different material was underneath, the dip of the stratification is such, that for more than $\frac{5}{6}$ of the length of the tunnel it must crop out, and show on the surface. In working from the central shaft, however, in consequence of the dip of the rock changing from east to west, and from its lying more nearly horizontal, it will be more difficult and costly to remove, and the same progress cannot be made as from the ends. I will therefore allow 55 feet per month as the average that can be made from the end workings, and 40 feet from the shaft workings.

The progress that can be made in sinking a shaft of the great depth required at the Hoosac, is altogether more uncertain and problematical, depending largely on the quantity of water met with. I

will assume, however, that it can be completed at an average rate of 21 feet per month, which is about the progress represented as having been made in sinking the present shaft. This will complete it in 48 months.

The cost of the tunnel, for a double track, exclusive of the 1,850 feet at the west end, I estimate at $80 per foot run, on the average. This to include all the miscellaneous and contingent expenses connected with the excavation, drainage, hoisting, pumping, ventilation, haulage of material, and also the arching of 2,000 feet if found necessary. The sinking of a central shaft, I estimate at $175 per foot down, including miscellaneous and contingent expenses, as above.

As to whether the cost would be reduced by the use of drilling machinery, I think somewhat uncertain. I have no reliable information of the cost at Mont Cenis, and there has been too little experience otherwise to determine satisfactorily. I will therefore assume that the cost will be the same as by hand labor. The saving to be effected by using machinery will thus be confined to the interest on capital expended. With these data, the time required and the cost on the several plans will be as follows: —

1.—By working from the Ends, and present Shaft only.

	Feet.	Feet.
Whole length of proposed tunnel, ...		24,416
Deduct portion already excavated at east end, .	2,400	
Deduct portion between present shaft and proposed western portal of tunnel, ...	1,850	4,250
Leaves to be excavated under mountain, ...		20,166

Time.—During the three years, while the 1,850 feet of tunnel and the open cutting at the western end are being excavated, the work will be in progress from the eastern end, and also from the present shaft, as follows:—

	Feet.	
From eastern end, 36 months at 55 feet, . . .	1,980	
" shaft " " " 40 " . . .	1,440	3,420
Leaving to be excavated at the end of 3 years, ...		16,746

and $16,746 \div 2 \times 55 = 153$ months, or say 13 years, which, added to the 3 years above, gives 16 years for the completion of the tunnel.

Cost. — 1,850 feet at west end, at $137.30, ...		$254,000
20,166 " under mountain, at $80.00, . . .		1,613,280
2,400 " already excavated, to be enlarged, at $25.00		60,000
1,200 " of open cutting, ...		100,000
5 miles of railway superstructure, at $9,000		45,000
Contingencies, including management, engineering, &c., ...		250,000
		$2,322,280

2. — By sinking a Central Shaft.

Length to be excavated under mountain, as in estimate No. 1, ... 20,166 feet.

Time. — During the four years, while the central shaft is being sunk, the work will be in progress from the eastern end, and also from the present shaft and western end: —

			Feet.	
48 months at eastern end,	at 55 feet, . . .		2,640	
36 " from present shaft	" 40 " . . .		1,440	
12 " from western end,	" 55 " . . .		660.	4,740
Leaving length of tunnel to be completed at the end of 4 years, ...				15,426

There will then be two end and two shaft faces to work from, which will give a monthly progress of 2 × 55 and 2 × 40 = 190 feet; and 15,426 ÷ 190 = 81 months, which, added to the 48 months in sinking the shaft, gives, say 11 years for the completion of the tunnel.

Cost. — 1,850 feet at west end,	at $137 30 . .	$254,000
20,166 " under mountain,	" 80 00 . .	1,613,280
2,400 " to be enlarged,	" 25 00 . .	60,000
Sinking central shaft, including machinery, 1,000 feet, at $175 00, ...		175,000
Open cutting, ...		100,000
5 miles of railway superstructure, at $9,000, ...		45,000
Contingencies, including engineering, ...		200,000
		$2,447,280

3. — By using Drilling Machinery as at Mont Cenis.

Length of tunnel to be excavated under mountain,
as in estimate No. 1, ... 20,166 feet.

Time. — The progress now made at the Mont Cenis Tunnel is represented to be 120 to 140 feet per month. At the Hoosac, a progress of 120 feet per month at each end, or 240 feet from both, would complete the tunnel in 84 months, or 7 years.

Cost. — Say, same as No. 2 estimate, ... $2,447,280

4. — By using Drilling Machinery from Central Shaft when completed, the time would be reduced to 6 years, and at an additional cost of probably $100,000.

INTEREST DURING CONSTRUCTION.

In the following comparative table of cost, I have added interest during construction, at the rate of 6 per cent. per annum, and assumed that the expenditure would be made at a rate nearly uniform : —

	STATEMENT.	Time to Complete.	Estimated Cost of Tunnel.	Interest during Construction	Total cost, including Interest.
1	Working from ends and present shaft,	Years.	$	$	$
	by hand labor, ...	16	2,322,280	1,515,600	3,837,880
2	By sinking a central shaft, ...	11	2,447,280	983,500	3,430,780
3	By power drills, as at Mont Cenis, .	7	2,447,280	575,300	3,022,580
4	" " " using central shaft, .	6	2,547,280	502,900	3,050,180

SUMMARY OF COST OF COMPLETING ROAD AND TUNNEL.

	Grading, Masonry, Bridging, and Superstructure.	Land Damages and Fencing.	Total.
Greenfield to Shelburne Falls, . . .	$186,759 00	$15,990 00	$202,749 00
Shelburne Falls to E. end of Tunnel,	184,211 80	33,030 00	217,241 80
Tunnel and open cutting, ...	2,447,280 00	2,000 00	2,449,280 00
Two miles of road from west end of Tunnel to North Adams, including station grounds, ...	55,000 00	12,500 00	67,500 00
Improving alignment of road from Greenfield to Tunnel, ...	150,000 00	5,000 00	155,000 00
	$3,023,250 80	$68,520 00	$3,091,770 80
Depot buildings and fixtures, ...			100,000 00
Locomotive engines and cars, ...			250,000 00
Miscellaneous, ...			50,000 00
			$3,491,770 80
Add interest during construction of road and tunnel, ...			1,000,000 00
Total, ...			$4,491,770 80

By calculating interest at 5 per cent., there would be a reduction of $200,000 on the estimated cost.

COMPARISON WITH OTHER ROUTES.

That a large amount of business would be done on the road, when the tunnel is completed, may be admitted. With Boston at one end, Troy and the Erie Canal at the other, and the boundless West beyond, there is no room for doubt. But to make such a road pay, it must not only have a large business, but one of such magnitude as to be somewhat commensurate with the cost of the work. The travel and freight between the places indicated have other channels which they now follow, and the question naturally presents itself, Will the road, if completed, have such advantages over these lines as to obtain sufficient business for its support? We have seen that the local business

is of no great magnitude, and would not sustain the road. We must, therefore, now inquire what are the comparative merits of the Troy & Greenfield Railroad with existing lines. Heretofore, in estimating the probable income, the through business has been mainly relied upon, and flour, for the Boston market and for exportation, has been the chief item. And, undoubtedly, any road that can carry this important staple cheaper than existing lines, and especially for exportation, will obtain a large amount of other freight, and be of great advantage to the State.

Flour is now brought from the West to Boston by five different routes:—

1st, via Western Railroad.
2d, " Rutland & Fitchburg Railroads.
3d, " Vermont Central.
4th, " Portland & Montreal.
5th, " Hudson River and Long Island Sound.

The following tables exhibit the length of railroad, and of lake and sea navigation on these several routes, from Lake Erie to Boston; and, in order to show, approximately, their relative merits, I have carried out the cost of transporting one ton of freight at the following rates, viz.:—

$1\frac{1}{2}$ cents per ton, per mile, on railroads.
$7\frac{1}{2}$ mills per ton, per mile, on canals.
5 mills per ton, per mile, for river navigation.
3 mills per ton, per mile, for lake navigation.
4 mills per ton, per mile, for sea-coast navigation.

These rates may be considered as the lowest at which flour or other heavy freight, in large quantities, can be carried throughout the season, and afford a living profit to the transporters.

STATEMENT SHOWING THE COST OF TRANSPORTING ONE TON OF FREIGHT FROM LAKE ERIE TO BOSTON, BY SEVERAL ROUTES.

By Erie Canal and Western Railroad.

Buffalo to Albany, by Erie Canal,	364 miles,	at	$7\frac{1}{2}$ mills,	$2 73	
Albany to Boston, by Western Railroad,	200 "	"	15 "	3 00	
Transhipment at Albany,				0 20	
	564				$5 93

By Welland Canal, Lake Ontario, Oswego and Erie Canals, and Western Railroad.

Welland Canal,	28 miles, at	$7\frac{1}{2}$	mills,	$0 21	
Welland Canal to Oswego, through Lake Ontario,	145 "	" 3	"	0 43	
Oswego to Albany, by Oswego & Erie Canals,	209 "	" $7\frac{1}{2}$	"	1 57	
Albany to Boston, by Western Railroad,	200 "	" 15	"	3 00	
Transhipments at Oswego and Albany,				0 40	
	582				$5 61

By Welland Canal, Lake Ontario, and Ogdensburg, Rutland, and Fitchburg Railroads.

Welland Canal,	28 miles, at	$7\frac{1}{2}$	mills,	$0 21	
Welland Canal to Ogdensburg, by Lake Ontario and St. Lawrence River,	230 "	" 3	"	0 69	
Ogdensburg to Boston by Railroad,	386 "	" 15	"	5 79	
Transhipment at Ogdensburg,				0 20	
	644				$6 89

By Welland Canal, Lake Ontario, and Ogdensburg and Vermont Central Railroads.

Welland Canal,	28 miles, at	$7\frac{1}{2}$	mills,	$0 21	
Welland Canal to Ogdensburg, by Lake Ontario and St. Lawrence River,	230 "	" 3	"	0 69	
Ogdensburg to Boston, by Railroad,	400 "	" 15	"	6 00	
Transhipment at Ogdensburg,				0 20	
	658				$7 10

By Welland Canal, Lake Ontario, St. Lawrence River, and Montreal & Portland Railroad.

Welland Canal,	28 miles, at	7½ mills,	$0 21	
Welland Canal to Montreal, by Lake Ontario and St. Lawrence River,	358 "	" 3 "	1 07	
Additional expense on the St. Lawrence Canals,	47 "	" 4 "	0 19	
Montreal to Portland, by railroad,	292 "	" 15 "	4 38	
Portland to Boston, by water,	115 "	" 4 "	0 46	
Transhipments at Montreal and Portland,			0 40	
	793			$6 71

By Erie Canal, Hudson River, and Long Island Sound.

Buffalo to Albany, by Erie Canal,	364 miles, at	7½ mills,	$2 73	
Albany to New York, by Hudson River,	145 "	" 5 "	0 72	
New York to Boston, by Long Island Sound,	338 "	" 4 "	1 35	
Transhipment at Albany and New York,			0 40	
	847			$5 20

By packets from Albany to Boston, one transhipment will be saved, making cost, ... $5 00

By Erie Canal and Troy & Greenfield Railroad.

Buffalo to Troy, by Erie Canal,	357 miles, at	7½ mills,	$2 68	
Troy to Boston, by Troy & Greenfield Railroad,	191 "	" 15 "	2 86	
Transhipment at Troy,			0 20	
	548			$5 74

By Welland Canal, Lake Ontario, Oswego and Erie Canals, and Troy & Greenfield Railroad.

Welland Canal, ...	28 miles,	at $7\frac{1}{2}$ mills,	$0 21
Welland Canal to Oswego, through Lake Ontario, ...	145 "	" 3 "	0 43
Oswego to Troy, by Oswego & Erie Canals, ...	202 "	" $7\frac{1}{2}$ "	1 51
Troy to Boston, by Troy & Greenfield Railroad, ...	191 "	" 15 "	2 86
Transhipments at Oswego and Troy, ...			0 40
	566		$5 41

From the above tables, it will be seen that the Tunnel route has the advantage over all the other railroad lines to Boston, of from 20 cents to $1.69 per ton, which, at ten barrels to the ton, is equal to 2 cents and 17 cents per barrel of flour. The water route, however, by Hudson River and Long Island Sound, is 41 cents per ton, or 4 cents per barrel cheaper than by the Tunnel route.

There are, no doubt, many modifying causes on the several routes which it is impossible to incorporate in such estimates, but these, it is believed, would not materially affect the general conclusions to be derived from the tables. No account is taken of difference in grade, curvature, &c., which, obviously, to some extent, would modify the calculations; the cost of fuel and conveniences for transhipment, also, have an important bearing in determining the price at which freight can be carried on railroads; also the facilities for obtaining return freights. It is found that the tonnage of the agricultural productions of the West is nearly four times greater than the return freights of merchandise and manufactures from the East.

The Rutland and Fitchburg, Vermont Central, and Montreal & Portland routes, from their greater length of railroad transport, cannot compete on equal terms for the through trade, with the Western and Troy & Greenfield Railroads; their paying business must, to a large extent be local, or in supplying districts to the north and east of Boston. The determination of the question, therefore, of the best route for the trade between Boston and the West, is reduced to a comparison between the Western and the Troy & Greenfield Railroads, and the water route by the Hudson River and Long Island Sound.

COMPARISON WITH THE WESTERN RAILROAD.

The following statements exhibit the leading characteristics of both routes: —

STATEMENT OF DISTANCES, GRADES, &c., VIA WESTERN RAILROAD.

	Length of Road. Miles.	Total Curvature in Deg.	Least Radius of Curvature.	MAXIMUM GRADES.		Rise and Fall in Ft.
				Ascending West.	Ascending East.	
Boston & Worcester Railroad, . . .	44½[1]	1,855[1]	600 feet for 900[1]	30 feet.	37½ feet.	714[1]
Western Railroad, ...	117½[1]	6,370[1]	882 feet for 490[1]	83 feet for 1½ miles.[1]	75½ for 5½ miles.	4,893[1]
Albany & West Stockbridge Railroad,	38.1[3]	1,869[3]	955 feet.[3]	42.8 feet for ¾ mile.[3]	42.3 feet for 1.85 miles.[3]	1,244[3]
	200.1	10,094				6,851

STATEMENT OF DISTANCES, GRADES, &c., VIA TUNNEL ROUTE.

	Length of Road. Miles.	Total Curvature in Degrees.	Least Radius of Curvature.	MAXIMUM GRADES.		Rise and fall in feet.
				Ascending W.	Ascending E.	
Fitchburg Railroad, ...	51.[1]	1,694[1]	818 ft.[1]	40.6[2]	34.3[2]	1,052[1]
Vermont & Massachusetts Railroad to Grout's Corner, . .	48.	2,908	924 ft.[1]	69.7[2]	52.2[2]	1,530
Grout's Corner to Greenfield, ...	7.66	607[1]	1,000 ft.[1]	. . . .	45 ft.[1]	249[1]
Troy & Greenfield Railroad to North Adams, ...	37.02	4,030	716 ft.	58.6	40	1,046.2
North Adams to State Line, ...	6.66	286	1,432 ft.	0.0	35.16	124.4
Southern Vermont Railroad, ...	6.	250	Unknown.	. . . .	. . . .	93
Troy & Boston Railroad, ...	34.66[3]	830[3]	1,910 ft.[3]	26.4 ft.[3]	41.3 ft.[3]	666[3]
	191.00	10,605				4,760.6

[1] Mass. Returns. [2] C. L. Stevenson. [3] N. Y. Returns.

COMPARATIVE VIEW OF THE WESTERN RAILROAD AND TUNNEL ROUTES, EXTENDING FROM BOSTON TO THE HUDSON RIVER.

STATEMENT.	Via Western Railroad to Albany.	Via Tunnel Route to Troy.	Difference.
Length, ...	200 miles.	191 miles.	9 miles.
Total amount of curvature, . .	10,094 degrees.	10,605 degrees.	511 deg.
Least radius of curvature, . . .	600 ft. for 900 ft.	716 ft. for 4,192 ft.	116 feet.
Maximum grade, ascending west,	83 ft. for 1½ miles.	69.7 feet.	13.3 "
" " " east,	75½ feet.	52.2 "	23.3 "
Total rise and fall, ...	6,851 "	4,760 "	2,091 "

The advantage, it will be observed, is uniformly in favor of the Tunnel route, except as to amount of curvature, but not to such a marked degree as would prevent a fair competition. If the comparison was extended to Schenectady by railroad from Albany and Troy, the saving in distance would be only 5 miles. But by canal, the difference would be increased to 16 miles in favor of the Tunnel route.

The great amount of curvature of small radius on the Troy & Greenfield Railroad would more than offset the shorter distance by that line, and I have no doubt that the Western road can be run over in the same time, and with greater safety than the Tunnel route. The reduced maximum grade on the latter is a decided advantage. A locomotive engine of 20 tons weight, with 14 tons on the drivers, will draw 138 tons gross on the Tunnel route, and 97 tons on the Western road.

Steep grades, however, are not found so objectionable in practice, on roads doing a general freighting business, as they were at one time considered. The increased weight of locomotive engines, and the distribution of that weight on a number of driving wheels, has overcome the leading mechanical difficulty; while, by using assistant engines, or a heavier class of engine, where the steep gradients occur, their effect on the cost of transportation is confined to that portion of the road.

Between Springfield and Pittsfield, where the steepest gradients occur on the Western Railroad, a heavier class of engine is used than on other portions of the road. And on the Vermont & Massachusetts road a heavier engine is necessary, in consequence of steeper grades, than on the Boston & Worcester, or Albany & West Stockbridge roads. The cost of locomotive power, which is the principal item affected by gradients, forms only about one third of the gross expenses of working a road, and of that one half only is much affected by the grade

or load. Two thirds of the expenses are independent of either grade or load. We accordingly find it difficult to distinguish, in the returns of railroad companies, the additional expenses in operating roads arising from grades. Frequently those with the highest are worked at the least expense. There are other causes which operate to some extent. Trains are rarely run with full or maximum loads. To accommodate business, numerous trains are required; and when roads receive a material access of business, it is met more frequently by increasing the number of trains than by increasing the load. This is universally the case with passenger travel. And with freight, in order to meet the fluctuations in the amount offered, and prevent accumulation at the depots, it is found advantageous to run extra trains. There are exceptions to this general rule, as in coal railroads, where the trains can always be run with maximum loads.

As a through line, then, from the Hudson River to Boston, the Tunnel route will divide the business with the Western Railroad, and will have the advantage in the actual cost of transportation, of 2 cents per barrel of flour, due to its shorter length, and a further advantage of from 1 to $1\frac{1}{2}$ cents, due to its reduced maximum grade and summits. As a passenger road, I consider it inferior to the Western Railroad. The great amount of curvature of small radius on the Troy & Greenfield Railroad, unsuits it for fast driving.

COMPARISON WITH WATER ROUTE, VIA HUDSON RIVER AND LONG ISLAND SOUND.

By the tables, we find that the cost of carrying a barrel of flour is 4 cents less by packet from Albany to Boston than by the Tunnel route. There are several extra expenses, however, in shipping by water, which, although not paid as freight, are fairly chargeable to the cost by water. There are interest on capital employed, wharfage and insurance, and also deterioration of the flour from dampness by the sea voyage, which, together, amount probably to more than the difference above stated, of 4 cents per barrel.

Until the year 1847, Boston received her principal supply of flour from the West by water. But since then the quantity so received has been continually decreasing. In 1861, 980 barrels only were brought by water from Albany, and 14,084 from New York, while more than one million barrels were brought in on the several railroads. During the same year, 126,000 barrels were brought from Baltimore and Philadelphia, and 168,000 via Portland. Dealers give a decided preference to railroad transportation, even at some increase of cost.

During the winter, when the navigation of the Hudson is closed, the railroads monopolize the business of carrying flour, and generally increase their rates.

But during the summer, in ordinary times, the charges by water are lower than by rail. A reduction of a few cents per barrel, however, is of great importance, sufficient, in fact, when maintained, to turn the course of trade. How far the 3 or 4 cents, which I estimate the Tunnel route as possessing over the Western Railroad, would affect shipments by water from New York, Philadelphia, and Baltimore, I have not the means of determining.

If we admit that the water route possesses nearly equal advantages to the Tunnel route, Boston cannot, except by lower sea rates or other concessions, compete with New York in exporting flour. The freight and insurance from New York is against her, equal to 10 to 13½ cents per barrel. New York City, by means of the Erie Canal and Hudson River, possesses advantages for exporting breadstuffs that no railroad can neutralize. Canal boats, carrying 250 tons, can proceed from Buffalo to New York without breaking bulk, thus saving delay and expense of transhipment. Frequently flour and other western products are unloaded directly from the boats into the vessel which is to carry them across the ocean. Fleets of these canal boats and barges are nightly towed down the river, during the season of navigation, at a cost of from 3 to 6 cents per ton for towage for the whole distance. No railroad can compete with such means of transportation. The Hudson River and the Harlem Railroads make no pretence of doing so for agricultural productions, which, being of considerable bulk and weight in proportion to their value, seek the cheapest conveyance without much regard to the rapidity of movement, while merchandise and manufactures seek, in proportion to their greater value, more speedy transport, without much reference to cost, and therefore are, to a considerable extent, sent by rail. The former includes by far the largest amount of tonnage moved.

It is not alone in her water communications that New York has the advantage over Boston in her connections with the West; her railroad routes are also shorter. Thus, from Buffalo to New York by the Erie Railroad is 423 miles, and by the New York Central and Hudson River Railroads 443 miles, while from Buffalo to Boston by the New York Central and Western Railroads is 498 miles, and by the Tunnel route it will be 493 miles. A difference of 50 to 75 miles in favor of New York.

Boston, on the other hand, has the advantage of being some 200 miles near Liverpool, and it is claimed that her harbor has deeper water and better facilities for the despatch of vessels than New York;

also, that her port charges are less. But these again at present are to a certain extent neutralized by the greater advantages which New York affords for obtaining return freights.

It has been claimed that any increase of through business could be done more cheaply by the Western Railroad than by a new road; that it would be a tax on the public to support both. This view of the subject, as applied to the Western and Troy & Greenfield roads, is narrow and limited. They are far apart, from 20 to 30 miles for three fourths of the distance; and while for the Boston or through business they would be competing lines, each would have its own section of country to supply and accommodate.

The following table exhibits the saving in distance effected by the Tunnel route, to the principal cities and manufacturing towns in Northern and Eastern Massachusetts:—

TABLE OF DISTANCES BY RAILROAD FROM TROY AND FROM ALBANY.

TOWNS.	From Albany via Western R. R.	From Troy via Tunnel Route.	Distance saved by Tunnel Route.
	Miles.	Miles.	Miles.
Boston, ...	200	191	9
Lowell, ...	201	172	29
Nashua, ...	202	173	29
Manchester, N. H., ...	219	190	29
Lawrence, ...	214	185	29
Salem, via Boston, ...	216	207	9
Newburyport, via Boston, ...	236	227	9
Portsmouth, via Lowell, ...	256	224	32
Groton Junction, ...	184	155	29
Fitchburg, ...	182	140	42
Sterling Junction, ...	168	154	14
Lancaster, ...	175	161	14
Greenfield, ...	138	84	54
North Adams, ...	69	48	21
Northampton, via Westfield, ...	107	103	4
Worcester, ...	156	166	

Competition is the life of business; it develops resources, which, without its stimulating effects would lie dormant, and without it individuals as well as corporations seek their own interests, without consulting those of the public.

It is but a short time, comparatively speaking, since the Erie and Pennsylvania Canals were the only public works for transporting freight to or from the West. The New York Central, the Erie, Baltimore & Ohio, and Pennsylvania Central Railroads have all been brought into use in succession, without affecting the receipts of the other lines, which have all continued to increase. And in New England, the Western Railroad, the Vermont Central, the Rutland, and the Portland routes have been opened without interfering seriously with the receipts of each other; they may, no doubt. have prevented a more rapid increase on the older roads, but it is difficult to trace any marked diminution in their previous receipts. The same, undoubtedly, will be the result by opening the Troy & Greenfield Railroad, more especially as it will be many years, even if vigorously prosecuted, before it can interfere or compete with the business of existing lines.

That some of these railroads do not now do a profitable business is due to the fact that they possess no advantages, but are inferior to the older lines.

When the Western Railroad was commenced, the total tonnage coming to tide water by Erie and Champlain Canals, was 600,000 tons. It now amounts to over 3,000,000 tons.

HOW SHOULD THE WORK BE COMPLETED — BY A CORPORATION OR BY THE STATE?

Looking at the fact that it is more than twelve years since the charter was granted for the construction of the road, and eight years since the pledge of the State was given for a loan of $2,000,000 to aid the work, and recollecting that it has been kept continually before the public during this long period, and great efforts made to raise the necessary means for its construction, but without success, we may, I think, accept these facts as evidence, if not of the want of commercial value in the project, at least as evidence of the inability of a corporation to carry it through without further aid. And, admitting that it is desirable and for the interests of the State that the work

should be completed, the question occurs whether it should be further aided in the hands of a corporation, or be undertaken as a State work.

Government and State works are proverbially costly; and it would, in my opinion, be infinitely better for Massachusetts to increase her aid than to undertake the work as a State. How much additional aid might be necessary to induce a responsible corporation or capitalists to embark in the work, who by investing their own money would evince their confidence and determination to complete the work, and thus secure all the benefits of an interested, economical, and judicious management, perhaps can only be determined when parties of undoubted financial ability and integrity are willing to undertake it.

Had capitalists entire confidence in the feasibility of the tunnel and the commercial value of the work, the means would be speedily forthcoming. The Hannibal & St. Joseph Railroad, Sault St. Mary's Canal, Illinois Central Railroad, and many other works of internal improvement, may be cited as examples where individuals have embarked their capital, when otherwise aided, on the faith of the eventual commercial value of the works; which works would not have been undertaken for many years without such extraneous aid.

There is a limit, however, to granting aid to a project of this kind, beyond which it would not be advisable to go. Capitalists are chary of investing in projects which will require many years before they can expect returns. This, together with the want of confidence in the value of the work when completed, based on the unproductiveness of some of the existing lines which had calculated largely on through business for support, might prevent responsible parties from embarking in it, unless on condition of too large advances being made by the State.

That the tunnel is perfectly practicable, no one acquainted with what has already been accomplished on public works, and more especially in mining operations, can for a moment doubt. And I consider the question of its commercial value and the benefits to the State, local and general, as being the ruling or main considerations which should determine the advisability of its prosecution.

I have, however, neither data, time, nor ability to go fully into these subjects, even if they had been embraced in my instructions, and present them within the time you require, the surveys and esti-

mates have occupied me so fully since their commencement in September last. But your Board are so fully qualified to decide, I pass them over with the single expression of opinion, that the Hoosac Tunnel, although its construction may be delayed, is destined eventually to be completed.

I have the honor to be, sir,

Your most obedient servant,

JAMES LAURIE, C. E.

TABLE No. 1.

TABLE OF GRADES ON PRESENT LOCATION OF THE TROY & GREENFIELD RAILROAD FROM GREENFIELD TO NORTH ADAMS.

Distance from Greenfield in Miles.	Length of Grade in Miles.	Grade per Mile in Feet.	Total.		Elevation of Grade above Tide Water.	LOCALITY.
			Ascent in Feet.	Descent in Feet.		
0.000	. . .	. . .	. . .	. . .	182.4	Greenfield.
0.189	0.189	31.68	6.2	. . .	188.6	Green River.
1.457	1.268	58.63	74.4	. . .	263.0	
1.645	0.189	31.68	6.0	. . .	269.0	Sheldon Brook.
2.083	0.438	56.24	24.5	. . .	293.5	
2.273	0.189	13.20	2.5	. . .	296.0	
2.462	0.189	26.40	. . .	5.0	291.0	
2.651	0.189	10.56	2.0	. . .	293.0	
2.841	0.190	36.96	. . .	7.0	286.0	Hawkes' Ravine.
2.992	0.151	33.00	5.0	. . .	291.0	
3.257	0.266	33.94	. . .	9.0	282.0	
3.276	0.018	Level.	. . .	. . .	282.0	
3.636	0.360	20.50	7.0	. . .	289.0	
3.996	0.360	20.50	. . .	7.0	282.0	
4.015	0.019	Level.	. . .	. . .	282.0	
4.280	0.265	41.48	11.0	. . .	293.0	East end of Stillwater trestle bridge.
5.246	0.966	17.60	. . .	17.0	276.0	
5.568	0.322	34.15	. . .	11.0	265.0	
6.382	0.814	18.42	. . .	15.0	250.0	
7.803	1.421	21.82	. . .	31.0	219.0	Near Bardwell's Ferry.
8.617	0.814	Level.	. . .	. . .	219.0	
13.030	4.413	50.16	221.35	. . .	440.35	Opposite Shelburne Falls.
13.275	0.245	23.05	5.65	. . .	446.00	Opposite Shelburne Falls.
14.317	1.042	48.96	51.00	. . .	497.00	
14.753	0.436	39.03	. . .	17.0	480.0	

TABLE No. 1.—Continued.

TABLE OF GRADES.

Distance from Greenfield in Miles.	Length of Grade in Miles.	Grade per Mile in Feet.	Total. Ascent in Feet.	Total. Descent in Feet.	Elevation of Grade above Tide Water.	LOCALITY.
15.359	0.606	13.20	. . .	8.0	472.0	Near Clesson's Brook.
15.548	0.189	Level.	. . .	. . .	472.0	
16.040	0.492	26.40	13.0	. . .	485.0	
17.915	1.875	8.53	16.0	. . .	501.0	
19.815	1.900	14.21	27.0	. . .	528.0	
20.705	0.890	10.11	9.0	. . .	537.0	
21.235	0.530	Level.	. . .	. . .	537.0	
21.614	0.379	10.56	4.0	. . .	541.0	Bosrah Brook.
21.881	0.267	Level.	. . .	. . .	541.0	Near Charlemont.
22.941	1.060	18.86	20.0	. . .	561.0	Near Chickley River.
23.225	0.284	10.56	3.0	. . .	564.0	
23.698	0.473	27.46	13.0	. . .	577.0	Second crossing of Deerfield River.
24.360	0.662	24.14	16.0	. . .	593.0	
25.136	0.776	25.76	20.0	. . .	613.0	
25.590	0.454	Level.	. . .	. . .	613.0	
26.404	0.814	41.13	33.5	. . .	646.5	Near Zoar Bridge.
26.915	0.511	16.62	8.5	. . .	655.0	
27.294	0.379	10.56	4.0	. . .	659.0	
27.864	0.570	21.47	12.2	. . .	671.2	
28.243	0.379	41.71	15.8	. . .	687.0	
30.137	1.894	41.71	79.0	. . .	766.0	East end of Tunnel.
32.404	2.267	31.68	72.0	. . .	838.0	Summit inside of Tunnel.
32.631	0.227	Level.	. . .	. . .	838.0	
34.752	2.121	22.65	. . .	48.0	790.0	West end of Tunnel.
36.854	2.102	40.00	. . .	85.0	705.0	
37.018	0.164	21.10	. . .	3.56	701.44	North Adams.
			782.6	263.56		

TABLE No. 1.—Continued.

TABLE OF GRADES.—NORTH ADAMS TO STATE LINE.

Distance from Greenfield in Miles.	Length of Grade in Miles.	Grade per Mile in Feet.	Total.		Elevation of Grade above Tide Water.	LOCALITY.
			Ascent in Feet.	Descent in Feet.		
37.018	. . .	. . .	. . .	. . .	701.44	North Adams.
37.150	0.132	10.86	. . .	1.44	700.00	
38.798	1.648	35.16	. . .	58.00	642.00	
39.025	0.227	26.40	. . .	6.00	636.00	
39.707	0.682	35.16	. . .	24.00	612.00	Blackinton's Factory.
41.412	1.705	10.56	. . .	18.00	594.00	
41.980	0.568	5.28	. . .	3.00	591.00	
43.003	1.023	Level.	. . .	. . .	591.00	
43.666	0.663	21.12	. . .	14.00	577.00	State Line.
	6.648	. . .	. . .	124.44		

TABLE No. 2.

LOCATION OF THE TROY & GREENFIELD RAILROAD FROM GREENFIELD TO NORTH ADAMS.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
0.	. . . . . .	. . .	Greenfield.
10.00	7° 7½′ Left.	1,000	
18.36	N. 84° 00 W.	836	
28.48	3½° Left.	1,012	
47.00	S. 60° 34′ W.	1,852	
61.00	3° Right.	1,400	
75.00	N. 77° 27′ W.	1,400	
93.58	6° Left.	1,858	Sheldon Brook.
101.43	S. 8° 55′ E.	785	
104.67	3° Right.	324	
119.39	S. 0° 48′ W.	1,472	
126.38	4° Right.	699	
129.52	S. 28° 45′ W.	314	
133.82	4° Left.	430	
137.38	S. 11° 32′ W.	356	
145.88	2° Right.	850	
148.31	S. 28° 32′ W.	243	
157.74	4° Left.	943	Hawkes' Ravine.
163.33	S. 9° 12′ E.	559	
170.55	6° Right.	722	
212.98	S. 38° 08′ W.	4,243	
220.59	3° Left.	761	
229.55	S. 11° 18′ W.	896	
239.23	6° Right.	968	
242.90	S. 69° 22′ W.	367	
245.46	6° Left.	256	
247.86	S. 53° 59′ W.	240	Stillwater.
256.11	6° Right.	825	
258.83	N. 76° 32′ W.	272	
266.05	6° Left.	722	
266.97	S. 60° 08′ W.	92	
278.57	8° Right.	1,160	
283.82	N. 27° 05′ W.	525	
286.32	6° Right.	250	
287.74	N. 12° 05′ W.	142	
291.97	6° Left.	423	
295.06	N. 37° 29′ W.	309	
299.10	6° Right.	404	
300.79	N. 13° 15′ W.	169	

TABLE No. 2.—Continued.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
303.34	6° Left.	255	
305.18	N. 28° 33′ W.	184	
307.76	6° Right.	258	
309.22	N. 13° 03′ W.	146	
311.60	6° Left.	238	Stickney's Brook.
315.08	N. 27° 19′ W.	348	
318.80	3° Right.	372	
324.50	N. 16° 09′ W.	570	
326.88	6° Right.	238	
329.00	N. 1° 53′ W.	212	
330.44	6° Left.	144	
332.43	N. 9° 51′ W.	199	
336.04	6° Left.	361	
351.00	N. 32° 31′ W.	1,496	
352.42	4° Left.	142	
355.85	N. 37° 40′ W.	343	
360.11	6° Right.	426	
360.90	N. 12° 06′ W.	79	
362.52	6° Left.	162	
363.70	N. 21° 50′ W.	118	
366.18	6° Right.	248	
367.39	N. 6° 58′ W.	121	
373.70	7° Left.	631	
376.05	N. 51° 09′ W.	235	
378.22	6° Left.	217	
379.35	N. 64° 11′ W.	113	
383.48	7° Right.	413	
385.47	N. 35° 17′ W.	199	
390.09	8° Left.	462	
398.00	N. 72° 15′ W.	791	
402.50	6° Right.	450	
406.02	N. 45° 15′ W.	352	Bardwell's Ferry.
410.16	6° Right.	414	
411.83	N. 20° 29′ W.	167	
414.40	3° Left.	257	
416.12	N. 28° 11′ W.	172	
424.84	4° Right.	872	
433.94	N. 6° 41′ E.	910	
438.56	8° Left.	462	Crossing Deerfield River.
441.78	N. 30° 15′ W.	322	
451.07	8° Left.	929	
453.00	S. 75° 25′ W.	193	

TABLE No. 2.—Continued.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
457.04	8° Right.	404	
460.25	N. 72° 15′ W.	321	
464.75	3° Right.	450	
468.91	N. 58° 47′ W.	416	
470.76	6° Right.	185	
478.15	4° Left.	739	
482.15	N. 77° 15′ W.	400	
485.50	6° Left.	335	
486.44	S. 82° 39′ W.	94	
487.35	4° Right.	91	
491.00	S. 86° 11′ W.	365	
491.92	4° Left.	92	
495.37	S. 82° 31′ W.	345	
502.12	6° Right.	675	
506.84	N. 56° 59′ W.	472	
512.06	5° Right.	522	
516.27	N. 30° 53′ W.	421	
520.63	3° Right.	436	
524.95	N. 17° 47′ W.	432	
530.25	4° Right.	530	
533.32	N. 3° 25′ E.	307	
534.90	2° Right.	158	
541.44	N. 6° 35′ E.	654	
543.78	6° Right.	234	
544.95	N. 20° 37′ E.	117	
550.20	3° Left.	525	
555.79	N. 4° 53′ E.	559	
568.00	6° Left.	1,221	
569.04	N. 68° 23′ W.	104	
574.80	6° Right.	576	
577.24	N. 33° 49′ W.	244	
581.93	5° Left.	469	
583.22	N. 57° 14′ W.	129	
589.83	6° Right.	661	
591.56	N. 17° 36′ W.	173	
596.12	4° Left.	456	
597.66	N. 35° 48′ W.	154	
601.45	4° Right.	379	
604.20	N. 20° 38′ W.	275	
610.12	5° Left.	592	
614.50	N. 50° 14′ W.	438	
616.53	2° Right.	203	

TABLE No. 2.—Continued.

STATIONS.	COURSES.	Lengths : Feet.	LOCALITY.
621.90	N. 46° 10′ W.	537	
623.20	4° Left.	130	
633.77	N. 51° 22′ W.	1,057	
639.09	6° Right.	532	
640.43	N. 19° 28′ W.	134	
642.20	5° Right.	177	
643.30	N. 10° 38′ W.	110	
645.74	5° Right.	244	
647.30	N. 1° 34′ E.	156	
650.53	6° Left.	323	
660.00	N. 17° 48′ W.	947	
663.78	4° 45′ Left.	378	
673.86	N. 35° 43′ W.	1,008	
678.21	6° Right.	435	
680.20	N. 9° 37′ W.	199	
685.16	6° Left.	496	Shelburne Falls.—Between 691 and 692 = 194½′.
692.59	N. 39° 23′ W.	837½	
700.34	8° Right.	775	
710.58	N. 22° 33′ E.	1,024	
713.83	6° Right.	325	
719.03	N. 42° 03′ E.	520	
724.05	6° Left.	502	
730.40	N. 11° 56′ E.	635	
736.77	6° Left.	637	
747.20	N. 26° 20′ W.	1,043	
751.00	4° Left.	380	
751.38	1° 19′ Left.	38	
754.28	N. 42° 02′ W.	290	
763.18	6° Left.	890	
765.42	S. 84° 34′ W.	224	
773.60	6° Right.	818	
783.65	N. 46° 26′ W.	1,005	
792.27	6° Left.	862	
795.00	S. 81° 51′ W.	273	
799.67	4° Right.	467	
803.16	N. 79° 28′ W.	349	
808.16	5° Left.	500	
810.60	S. 75° 32′ W.	244	
812.34	6° Right.	174	
813.35	S. 85° 58′ W.	101	Glesson's River.
817.65	6° Right.	430	
848.96	N. 68° 14′ W.	3,131	

TABLE No. 2.—Continued.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
854.19	4° Left.	523	
882.31	N. 89° 08′ W.	2,812	
885.54	4° Left.	323	
901.30	S. 77° 56′ W.	1,576	
905.25	3° Right.	395	
911.50	S. 89° 48′ W.	625	
913.41	6° Left.	191	
915.06	S. 78° 20′ W.	165	
922.65	4° Right.	759	
934.18	N. 71° 18′ W.	1,153	
938.98	4° Left.	480	
943.28	S. 89° 30′ W.	430	
949.04	3° Right.	576	
953.43	N. 73° 13′ W.	439	
959.25	6° Right.	582	
962.22	N. 38° 18′ W.	297	
966.43	6° Left.	421	
968.46	N. 63° 34′ W.	203	
974.27	6° Left.	581	Between 985 and 986 = 131 feet.
987.71	S. 81° 35′ W.	1,375	
990.08	4° Right.	237	
991.44	N. 88° 56′ W.	136	
994.58	4° Left.	314	
997.64	S. 78° 31′ W.	306	
1004.56	6° Right.	692	
1012.45	N. 59° 57′ W.	789	
1014.87	4° Right.	242	
1018.05	N. 50° 16 W.	318	
1024.15	6° Left.	610	
1025.13	N. 86° 52′ W.	98	
1032.31	6° Right.	718	
1034.12	N. 43° 47′ W.	181	
1037.26	3° Right.	314	
1050.00	N. 34° 22′ W.	1,274	
1052.60	3° Right.	260	
1060.76	N. 26° 34′ W.	816	
1064.58	6° Left.	382	
1070.62	2° Left.	604	
1081.03	N. 61° 34′ W.	1,041	
1089.10	6° Left.	807	
1090.67	S. 70° 01′ W.	157	

TABLE No. 2.—Continued.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
1096.78	6° Right.	611	
1106.78	N. 73° 19′ W.	1,000	
1117.00	2° Left.	1,022	Opposite Charlemont Centre.
1120.00	S. 86° 15′ W.	300	
1122.34	6° Left.	234	
1123.55	S. 72° 13′ W.	121	
1131.44	6° Right.	789	
1134.80	N. 60° 27′ W.	336	
1138.80	6° Left.	400	
1140.33	N. 84° 27′ W.	153	
1144.56	6° Right.	423	
1157.22	N. 59° 04′ W.	1,266	
1161.22	2° Left.	400	
1166.18	N. 67° 04′ W.	496	
1170.81	2° 30′ Right.	463	
1172.28	N. 55° 30′ W.	147	
1174.28	2° 30′ Right.	200	
1180.89	N. 50° 30′ W.	661	
1183.50	3° Right.	261	
1185.12	N. 42° 40′ W.	162	
1191.00	6° Left.	588	
1192.14	4° Left.	114	
1195.20	N. 82° 31′ W.	306	
1201.63	6° Right.	643	
1202.10	N. 43° 56′ W.	47	Chickley's River.
1204.16	6° Right.	206	
1206.62	N. 31° 34′ W.	246	
1208.16	4° Left.	154	
1215.13	N. 39° 44′ W.	697	
1219.57	6° Left.	444	
1227.72	N. 66° 24′ W.	815	
1238.72	4° Right.	1,100	
1258.85	N. 22° 24′ W.	2,013	
1265.93	4° Left.	708	
1269.26	N. 50° 44′ W.	333	
1274.03	5° Left.	477	
1285.91	N. 74° 35′ W.	1,188	Deerfield River.
1296.00	6° Right.	1,009	
1302.14	5° Right.	614	
1306.74	N. 14° 11′ E.	460	
1309.79	4° Left.	305	

TABLE No. 2.—CONTINUED.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
1315.70	N. 1° 59′ E.	591	
1320.14	6° Left.	444	
1325.36	N. 24° 39′ W.	522	
1328.13	3° Left.	277	
1337.52	N. 32° 57′ W.	939	
1355.60	4° Left.	1,808	
1358.60	S. 74° 44′ W.	300	
1362.25	6° Right.	365	
1364.07	N. 83° 22′ W.	182	
1368.21	6° Left.	414	
1381.65	S. 71° 50′ W.	1,344	
1384.22	6° Right.	257	
1386.29	S. 87° 15′ W.	207	
1399.00	6° Right.	1,271	
1401.00	5° Right.	200	Zoar Bridge.
1405.80	4° Right.	480	
1409.40	N. 12° 43′ E.	360	
1416.00	2° Right.	660	
1419.00	N. 25° 55′ E.	300	
1421.60	6° Left.	260	
1428.26	N. 10° 19′ E.	666	
1430.45	4° Right.	219	
1432.45	N. 19° 05′ E.	200	
1435.57	6° Left.	312	
1445.88	N. 0° 22′ E.	1,031	
1454.20	6° Left.	832	
1456.75	N. 49° 33′ W.	255	
1464.00	6° Left.	725	
1465.00	S. 86° 57′ W.	100	
1467.50	4° Left.	250	
1470.00	6° Left.	250	
1471.22	4° Left.	122	
1485.72	S. 57° 04′ W.	1,450	
1491.40	6° Right.	568	
1495.16	S. 88° 52′ W.	376	
1499.08	4° Left.	392	
1510.75	S. 73° 13′ W.	1,167	
1522.48	6° Right.	1,173	
1527.25	N. 36° 24′ W.	477	
1532.69	3° Left.	544	
1552.64	N. 52° 43′ W.	1,995	

TABLE No. 2.—Continued.

STATIONS.	COURSES.	Lengths: Feet.	LOCALITY.
1559.00	4° Right.	636	
1570.81	N. 27° 17′ W.	1,181	
1574.69	4° Left.	388	
1582.53	N. 42° 49′ W.	784	
1590.53	5° Left.	800	East end of Tunnel.
1753.92	N. 81° 08′ W.	16,308	Between 1590.53 and 1591 = 22 feet.
1753.92	Angle 0° 26′ Left.		
1840.70	N. 81° 34′ W.	8,678	Near west end of Tunnel.
1856.86	4° Right.	1,616	
1911.00	N. 16° 42′ W.	5,414	
1921.62	2° Left.	1,062	
1953.65 1898.00	N. 38° 07′ W.	3,203	North Adams.

TABLE OF CURVATURE ON TROY & GREENFIELD RAILROAD.

Number of Curves.	Description.	Length of each Class of Curve.	Total Curvature.
8	2° or 2,865 feet radius,	0.946 miles.	
17	3° " 1,910 " "	1.480 "	
35	4° " 1,432½ " "	3.483 "	
11	5° " 1,146 " "	0.942 "	4030°
72	6° " 955 " "	7.101 "	
3	7° 7½′ " 764 to 818½ " "	0.387 "	
6	8° " 716.2 " "	0.794 "	
152		15.133 miles.	
	Straight line, ...	21.885 "	
		37.018 miles.	

TABLE No. 3.

TABLE OF GRADES ON MR. EDWARDS' LOCATION, FROM GREENFIELD TO NORTH ADAMS.

Distance from Greenfield in Miles.	Length of Grade in Miles.	Grade per Mile in Feet.	Total. Ascent in Feet.	Total. Descent in Feet.	Elevation of Grade above Tide Water.	LOCALITY.
0.000	. . .	. . .	. . .	. . .	184.00	Greenfield.
1.900	1.900	44.21	84.00	. . .	268.00	
3.030	1.130	46.02	52.00	. . .	320.00	
4.125	1.095	25.57	28.00	. . .	348.00	
4.165	0.040	Level.	. . .	. . .	348.00	
4.850	0.685	26.28	. . .	18.00	330.00	
5.720	0.870	Level.	. . .	. . .	330.00	
5.980	0.260	18.85	. . .	5.00	325.00	
7.120	1.140	Level.	. . .	. . .	325.00	Near Bardwell's Ferry.
8.630	1.510	13.20	20.00	. . .	345.00	Dragon Brook.
9.770	1.140	26.40	30.00	. . .	375.00	
12.040	2.270	26.40	59.00	. . .	434.00	
12.410	0.370	Level.	. . .	. . .	434.00	
14.500	2.090	26.40	56.00	. . .	490.00	
16.400	1.900	13.20	25.00	. . .	515.00	
17.160	0.760	Level.	. . .	. . .	515.00	
18.480	1.320	18.85	25.00	. . .	540.00	
19.240	0.760	6.60	5.00	. . .	545.00	
20.180	0.940	Level.	. . .	. . .	545.00	Mile Brook.
20.560	0.380	13.20	5.00	. . .	550.00	
21.320	0.760	Level.	. . .	. . .	550.00	
22.100	0.780	26.40	25.00	. . .	575.00	
23.210	1.110	21.12	20.00	. . .	595.00	Deerfield River.
28.980	5.770	31.27	180.00	. . .	775.00	
29.445	0.465	32.25	15.00	. . .	790.00	
31.345	1.900	31.68	60.00	. . .	850.00	Summit inside of Tunnel.
31.440	0.095	Level.	. . .	. . .	850.00	Summit inside of Tunnel.
33.690	2.250	26.62	. . .	60.00	790.00	Near west end of Tunnel.
35.880	2.190	41.93	. . .	94.00	696.00	North Adams.
			689.00	177.00		

TABLE No. 3.—Continued.

ABSTRACT OF GRADIENTS ON MR. EDWARDS' LOCATION.

GRADIENTS.	Ascending West.	Descending West.	Total.
	Miles.	Miles.	Miles.
Level.	. . . .	. . . .	4.975
From 0 to 10 feet per mile, . . .	0.760	. . . .	0.760
" 10 to 20	5.110	0.260	5.370
" 20 to 30	8.485	2.935	11.420
" 30 to 40	8.135	. . . .	8.135
" 40 to 41.93	. . . .	2.190	5.220
" 40 to 46	3.030		
	25.520	5.385	35.880

TABLE No. 4.

TABLE OF CURVATURE ON MR. EDWARDS' LOCATION.

	Lengths in Miles.	Total Miles.	Whole No. of Degrees of Curvature.	
1° Curve = 5,730 feet radius, . .	3.439	. . .	2287° 48′	
2° " = 2,865 " " . .	5.213	. . .		
3° " = 1,910 " " . .	3.906	. . .		
4° " = 1,432 " " . .	3.541	. . .		
5° " = 1,146 " " . .	0.975	. . .		
6° " = 955 " " . .	0.189	17.317		
Straight line, ...	. . .	18.563		
		35.880		

TABLE No. 5.

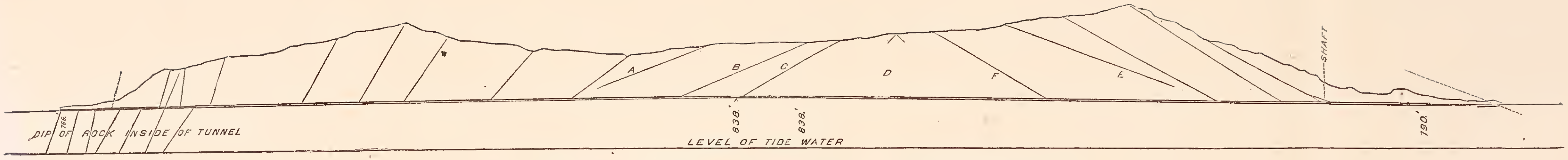
TABLE OF GRADES ON DEERFIELD ROUTE FROM VERMONT & MASSACHUSETTS RAILROAD TO BARDWELL'S FERRY.

Distance from Greenfield in Miles.	Length of Grade in Miles.	Grade per Mile in Feet.	Total. Ascent in Feet.	Total. Descent in Feet.	Elevation of Grade above Tide Water.	LOCALITY.
0.000	. . .	. . .	. . .	. . .	165.8	Vermont & Massachusetts Railroad
0.568	0.568	Level.	. . .	. . .	165.8	
0.992	0.424	25.95	11.0	. . .	176.8	
1.068	0.076	Level.	. . .	. . .	176.8	Connecticut River Railroad.
2.223	1.155	19.73	. . .	22.8	154.0	
2.640	0.417	Level.	. . .	. . .	154.0	
3.094	0.454	28.63	. . .	13.0	141.0	Deerfield Centre.
3.587	0.493	Level.	. . .	. . .	141.0	
3.890	0.303	23.10	7.0	. . .	148.0	Deerfield River.
4.155	0.265	Level.	. . .	. . .	148.0	
5.518	1.363	34.47	47.0	. . .	195.0	
5.803	0.285	Level.	. . .	. . .	195.0	
8.111	2.308	10.40	24.0	. . .	219.0	Bardwell's Ferry.
			89.0	35.8		

TABLE No. 6.

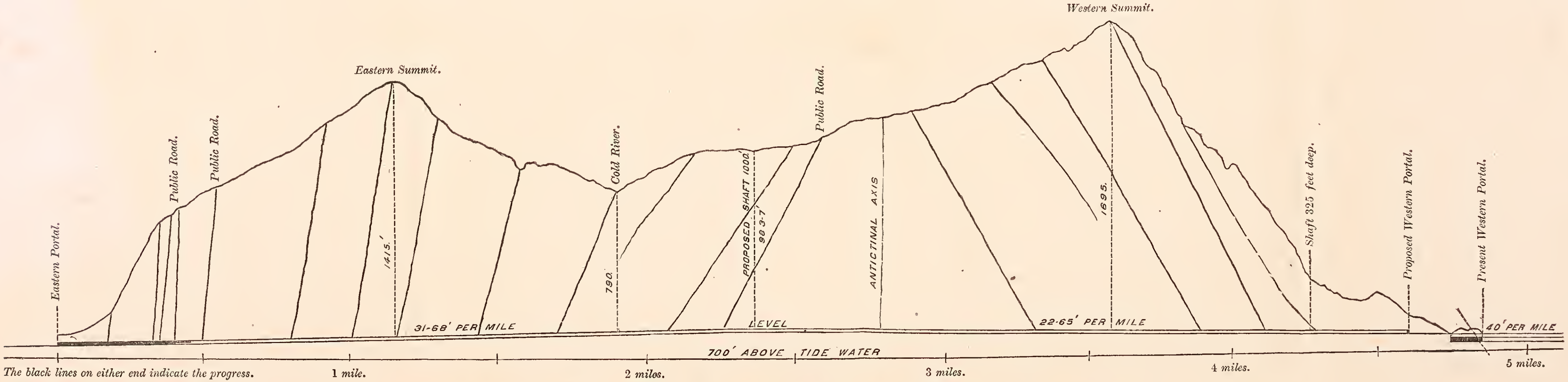
TABLE OF GRADES ON VERMONT & MASSACHUSETTS RAILROAD AND TROY & GREENFIELD RAILROAD, EMBRACED BETWEEN THE POINTS OF JUNCTION WITH THE DEERFIELD ROUTE.

Distance from Vt. & Mass. R. R. in Miles.	Length of Grade in Miles.	Grade per Mile in Feet.	Total.		Elevation of Grade above Tide Water.	LOCALITY.
			Ascent in Feet.	Descent in Feet.		
0.	. . .	. . .	. . .	. . .	165.8	Vermont & Mass.R.R.
0.227	0.227	38.72	. . .	8.8	157.0	" " "
0.416	0.189	Level.	. . .	. . .	157.0	" " "
0.965	0.549	34.59	19.0	. . .	176.0	" " "
1.325	0.360	17.78	6.4	. . .	182.4	Greenfield.
1.514	0.189	31.68	6.2	. . .	188.6	Green River
2.782	1.268	58.63	74.4	. . .	263.0	
2.970	0.188	31.68	6.0	. . .	269.0	Sheldon Brook
3.408	0.438	56.24	24.5	. . .	293.5	
3.598	0.190	13.20	2.5	. . .	296.0	
3.787	0.189	26.40	. . .	5.0	291.0	
3.976	0.189	10.56	2.0	. . .	293.0	
4.166	0.190	36.96	. . .	7.0	286.0	Hawkes' Ravine.
4.317	0.151	33.00	5.0	. . .	291.0	
4.582	0.265	33.94	. . .	9.0	282.0	
4.601	0.019	Level.	. . .	. . .	282.0	
4.961	0.360	20.50	7.0	. . .	289.0	
5.321	0.360	20.50	. . .	7.0	282.0	
5.340	0.019	Level.	. . .	. . .	282.0	
5.605	0.265	41.48	11.0	. . .	293.0	
6.571	0.966	17.60	. . .	17.0	276.0	End of Stillwater Trestle Bridge
6.893	0.322	34.15	. . .	11.0	265.0	
7.707	0.814	18.42	. . .	15.0	250.0	
9.033	1.326	23.38	. . .	31.0	219.0	Bardwell's Ferry.
	9.033		164.0	110.8		
				164.0		
				274.8		



SECTION OF HOOSAC MOUNTAIN, ON NATURAL SCALE, SHOWING DIP OF ROCK.

Scale 2000 feet per inch.



PROFILE OF THE HOOSAC MOUNTAIN, ON TUNNEL LINE OF THE TROY AND GREENFIELD RAILROAD.

Horizontal Scale, 2000 feet to an inch.
Vertical " 600 " " "

1 180

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